MEMOIRS

OF THE

GEOLOGICAL SURVEY OF GREAT BRITAIN,

AND OF THE

MUSEUM OF ECONOMIC GEOLOGY

IN

LONDON.

LONDON:
PRINTED BY WILLIAM CLOWES AND SONS,
STAMFORD STREET.

12 2/4 vols

JC Branner

MEMOIRS

OF THE

GEOLOGICAL SURVEY

OF

GREAT BRITAIN,

AND OF THE

MUSEUM OF ECONOMIC GEOLOGY IN LONDON.

VOL. I.

PUBLISHED BY ORDER OF THE LORDS COMMISSIONERS OF
HER MAJESTY'S TREASURY.

LONDON:
PRINTED FOR HER MAJESTY'S STATIONERY OFFICE:
PUBLISHED BY
LONGMAN, BROWN, GREEN, AND LONGMANS.
M DCCC XLVI.

5

NOTICE.

The Geological Survey of Great Britain having been transferred from the Ordnance to the charge of the Chief Commissioner of Her Majesty's Woods, Works, and Land Revenues, in April, 1845, and its extension into Ireland at the same time ordered, so that the Geological Survey became that of the United Kingdom, it was considered expedient that, instead of publications by a single person (such as the Report on the Geology of Cornwall, Devon, and West Somerset, by Sir Henry De la Beche, or the work on the Palæozoic Fossils of Cornwall, Devon, and West Somerset, by Professor John Phillips) Memoirs by different persons engaged on the Survey, and contained in the same volume should be substituted.

It was further thought advisable that these Memoirs should be divided into two series, one for Great Britain, the other for Ireland; the volumes of the former also containing memoirs by the officers attached to the Museum of Economic Geology in London, while those of the latter also included such communications from the Museum of Economic Geology in Dublin, as the head of that establishment might consider appropriate.

The present volume is the first of the series for Great Britain. It has so occurred that into it subjects connected with general views in geology and its applications, have been chiefly introduced. It must not, however, be hence inferred that local descriptions of country will not be frequent, it being desirable to publish the two classes of memoirs, both being alike necessary properly to illustrate the various subjects to be considered in this work. The second volume of the series for Great Britain will commence with an elaborate and detailed description of the Malvern Hills, compared with the Palæozoic districts of Abberley, &c., by Professor John Phillips.

A series of engraved representations of British fossils, illustrative of the researches of the Geological Survey of Great Britain and Ireland,

and in which it is intended to figure from as complete materials as can be obtained the several species in all their modifications of form and structure, will, from time to time, be issued, and in part accompany the volumes of Memoirs. Of these engravings a number will be given in the second volume of the present series. These figures, with their descriptions, will thus eventually form a comprehensive and separate work on British Fossils.

In addition to the sheets of the Geological Maps (those of the Ordnance coloured geologically) which appear as heretofore, when particular districts have been properly examined by the Survey, large plates of sections are now published. These, which may be obtained in separate sheets to illustrate any particular portion of country, are of two kinds; one series being on a scale of six inches to the mile, both for height and distance, so that the sections should truly represent nature; the other on one of forty feet to the inch, so as to afford an insight into greater detail when such may be necessary. It is hoped that these sections will be found valuable not only in illustration of geological phenomena, but also to the miner and mineral proprietor, more especially in the coal districts.

It being desirable to show the means of instruction in mining, and the sciences connected with it, possessed by foreign nations, in order that such means may be compared with those within the reach of the British miner, the Mining Geologist of the Survey, has contributed to this volume notices of the Mining Academies of Saxony and Hungary, and of the Mining Establishment of France.

With the view of exhibiting the state of the mineral products of other countries relating directly or indirectly to those of our own, papers will occasionally be introduced similar to that contained in this volume upon the coal and lignite raised, and iron and steel manufactured in France, and it is proposed from time to time to present statistical details respecting the metals and useful minerals raised in the British Islands, such as is now given for the copper and tin of Cornwall by the Keeper of Mining Records, in the Museum of Economic Geology in London, in whose office it is hoped valuable information respecting the mineral wealth of Great Britain will be finally accumulated for public use.

TABLE OF CONTENTS.

Page

I. *On the Formation of the Rocks of South Wales and South Western England.* By SIR HENRY T. DE LA BECHE, Director-General of the Geological Surveys of the United Kingdom 1

II. *On the Denudation of South Wales and the adjacent Counties of England.* By ANDREW C. RAMSAY, F.G.S., Director of the Geological Survey of Great Britain 297

III. *On the Connexion between the Distribution of the existing Fauna and Flora of the British Isles, and the Geological Changes which have affected their area, especially during the epoch of the Northern Drift.* By EDWARD FORBES, F.R.S., L.S., G.S., Professor of Botany at King's College, London, Palæontologist to the Geological Survey of the United Kingdom . 336

IV. *Remarks on the Influence of Magnetism and Voltaic Electricity on Crystallization and other conditions of matter.* By ROBERT HUNT, Keeper of Mining Records 433

V. *On the Gases evolved during the Formation of Coal.* By DR. LYON PLAYFAIR, Chemist to the Geological Survey of Great Britain 460

VI. *Note on the Gogofau, or Ogofau, Mine, near Pumpsant, Caermarthenshire.* By WARINGTON W. SMYTH, M. A., Cambridge, F.G.S., Mining Geologist to the Geological Survey of the United Kingdom 480

VII. *An Account of the Mining Academies of Saxony and Hungary.* By WARINGTON W. SMYTH, M.A., Cambridge, Mining Geologist to the Geological Survey of the United Kingdom . 485

VIII. *A Notice of the Mining Establishment of France* 495

IX. *An Account of the Coal and Lignite raised, and of the Iron and Steel manufactured in France* 501

X. *A Notice of the Copper and Tin raised in Cornwall.* By ROBERT HUNT, Keeper of Mining Records 510

MEMOIRS

OF THE

GEOLOGICAL SURVEY

OF

GREAT BRITAIN, &c.

On the formation of the Rocks of South Wales and South Western England. By Sir Henry T. De la Beche, F.R.S., Director General of the Geological Surveys of the United Kingdom.

It would appear desirable that, from time to time during the progress of the Geological Survey, as sufficient portions of country have been carefully examined, the probable causes which have led to the formation of the rocks composing such districts should be investigated; as, by adopting this course, we may not only be led duly to appreciate the probable condition of these portions of land at different geological times, but also such causes themselves,—those influencing the production of rocks generally. With this view it is proposed to see how far the facts brought to light respecting the geological structure of South Wales and of South Western England may enable us to attain this important object.

It may be advisable, before we inquire into these facts, to take a brief view of the effects of the igneous action and of the deposit of mineral matter, chemically or mechanically, from or by means of seas, estuaries, and lakes, as they are at present known to us. By comparing this knowledge with the geological facts observed in the district, we shall see how it enables us satisfactorily to account for them, and how far other reasoning may be necessary.

First, of the igneous products. In various parts of the world ashes and cinders are violently driven out of apertures or vents into the air by expanding gases and vapours, and accumulate in conical heaps around the vents whence they have been expelled. From time to time melted rock is lifted up and overruns or breaks down, or through, the barrier of ashes and cinders, flowing in long lines to various distances, according to circumstances. Occasionally rents are produced in the mass of ashes and cinders, and into them the hot molten rock is forced, rising as any

viscous or liquid body would, until a balance to the pressure is effected. Many a volcano, if it could be so dissected that all the ashes and lapilli were removed, and the solid matter of the lava currents and dykes left, would, no doubt, present a singular skeleton,—one necessary to be borne in mind when we compare the products of sub-aerial volcanos with the rocks referable to igneous origin at previous geological epochs.

From changes of vent, cones of ashes and cinders, more or less braced together by lava currents and by dykes of lava, become intermingled with each other. Sometimes a large cone becomes studded around by others of minor dimensions; sometimes the most active vent changes its place, so as to leave part of the old crater and cone adjoining it. We can conceive that in a great volcanic region, such as Iceland, the intermixtures of lines and dykes of melted rock with ashes and cinders must be most complex.

Ashes are at times, and during great eruptions, poured forth in vast abundance, covering the adjacent country, and being occasionally transported by the winds even to great distances. These ashes, under many conditions of the relative position of the volcanos and the sea, fall abundantly into the latter; and the brooks and rivers often carry down such ashes washed into them by the rains; so that the sea bottom adjoining volcanic districts, and especially near volcanic islands, receives a coating of volcanic ashes and lapilli during eruptions in which these products were distributed around, the lapilli disappearing as the distance from the volcanic vent is increased.

When thus thrown into the sea, the ashes and cinders are subjected to the usual action of breakers, waves, tides, and currents. On the coast there is an intermingling of the various triturated portions of the shore rocks, in some places forming shingle beaches, at others sands. If there be much volcanic matter of various kinds, the shingle beaches possess that character; and where sandstones, limestones, and other rocks also occur, there is a mixture of these also.

Marine, lacustrine, and fluviatile creatures live among the ashes and lapilli, especially the former, as amid the mud, sands, and gravels resulting from the destruction of ordinary rocks; more especially after the ashes and cinders have become well washed, and any salts, arising from chemical compounds formed while within the influence of volcanic vapours, are removed. We can readily conceive much mixture of the calcareous matter of molluscs and other marine creatures with the ordinary ashes, and a continuous deposit containing little else than the materials vomited forth from volcanos in one place losing that character gradually in distance, so that it should be volcanic in one part of the area, of a mixed kind in another, and composed of ordinary mud, sand, and gravel, in a third portion; yet the whole, according to equal con-

ditions of temperature, depth, and kind of bottom, as regards mud, sand, and gravel, affording a similar fauna.

In deep seas the ashes would remain undisturbed at the bottom, mingled only with the marine animals living there, or with products chemically formed. Where finely comminuted detritus could be deposited from mechanical suspension, the discharge of volcanic ashes being sufficiently repeated, there would be alternations of such substances; and when from the action of waves in less depths the bottom could be occasionally stirred up, there might be an intimate mingling of volcanic ashes with sands and mud.

Some singular mixtures would be effected upon sea bottoms where, either from an accumulation of broken or whole shells and corals, or from calcareous matter chemically produced, limestones were forming, and ashes and lapilli were showered upon the sea above them. In cases where the quantity of the volcanic matter thus scattered over the surface was small, there might be a considerable intermixture of ashes and cinders with the calcareous matter, without materially injuring the marine creatures inhabiting the bottom; but when the volcanic discharges were so violent as to cause a considerable accumulation of ashes and cinders, there might be great destruction of the animal life existing on the bottom, and their harder parts would become permanently entombed, the whole eventually forming a solid bed.

The same volcanic causes would be greatly modified in their effects when in action beneath the level of the sea. Ashes being little else, commonly, than finely comminuted portions of the vitreous state of lava, requiring a certain freedom from mechanical pressure, could, independently of the absorption of several propelling gases and vapours by the water, scarcely be formed at considerable depths. Very near the surface they might be produced, and be mingled with the water; but until the crater was sufficiently raised that the discharges could be considered as sub-aerial, ashes could scarcely be dispersed so as to cover large areas.

At great depths in the sea we should expect that the molten rocks ejected from a volcanic vent would have a tendency to be flattened out by spreading, if the volcanic action were considerable, into somewhat broad sheets, thus differing materially from sub-aerial lava currents. In proportion as the pressure became less from the melted rock accumulating round the vents, and the process of cooling became much modified under less depth, so should we expect, under equal action, that the lava discharges would become thicker, extending to less distances around, thus gradually forming a sort of obtuse cone.

It should be borne in mind, that in proportion as the active vent rose in the sea, so would the mechanical pressure of the water be removed; and thus, the accumulations continuing, the volcano would gradually rise

to and above the surface of the waters, as is well known to have been the case in our own times. Ashes and cinders would be ejected to be washed away by the breakers, if the volcanic action were not sufficiently powerful to throw out barriers of lava, and thus keep the crater permanently above the sea, as has been the case with many a volcanic island.

Once above the sea, the ashes, cinders, and detritus from the volcanic rocks, produced in the ordinary manner from atmospheric influences, running water, and the action of breakers, would form mud, sand, and gravel around, on and in which molluscs and other animals would live; so that we should have nearly similar rocks, as regards mineral composition, accumulated from combined igneous and aqueous action, in the latter case intermingled probably with the remains of animal and vegetable life.

In some situations, such volcanic accumulations may rise boldly up from those depths usually termed considerable, as is the case with the Sandwich Islands; at others they may be distributed in shallower seas, the detritus and ashes from them becoming intermingled with the mechanically transported detritus of other rocks. We can readily imagine some singular mixtures of solid lava, cinders, and ashes, with ordinary mud, sand, and gravel, among which are dispersed the hard parts of molluscs and other animals. We may have masses of coral reefs entangled, and the calcareous matter incased amid lava, or beds of volcanic ashes, cinders, and conglomerate.

Let us now turn to those deposits or accumulations of matter which are effected by the action or through the agency of water. The decomposition of rocks from atmospheric influences, the transport of the decomposed parts by brooks and rivers, the wearing away of the various substances geologically termed rocks, by the mechanical action of these running waters, and the destructive effects of breakers on coasts, afford a mass of detrital matter to the sea, to be dealt with by it, and distributed according to a variety of conditions.

Independently of the matter thus mechanically suspended in, or moved by, waters, we have substances chemically mingled with them. The rains falling upon the land and infiltrating into it, come out as springs carrying with the water the soluble parts of the rocks they have passed through, the substances in solution varying according to the rocks thus traversed by the water. The rain falling on limestone countries and containing carbonic acid, obtained either in the atmosphere or from infiltration amid the decaying vegetation of the surface, dissolves the rock, and carries it away in the soluble form of a bicarbonate of lime, affording the clearest spring water, yet containing the needful material for the shells of molluscs and other creatures requiring carbonate of lime, and the elements of new limestone beds; in fact, in the latter case, invisibly removing limestone from one place to another.

In a similar manner, other substances are carried from situations where they have remained fixed from early geological times to form solid matter in new localities, often combined in a different manner, but still being merely again used, as it were, in keeping up a general mass of solid mineral matter on the surface of the globe.

In all decompositions of felspar or albite, so abundant in granitic and many trappean and volcanic rocks, by carbonic acid, the silica in its soluble state from silicate of potash or of soda, as the case may be, is carried away by water. This silica, when deposited in cracks, forms quartz, and compounds with other substances, or cements sands together, forming the sandstones of future times. Independently of siliceous deposits, as from the Geisers of Iceland, it is appropriated even by marine animals, such as sponges and some molluscs, for parts of their structure essential to their well-being.

The soluble matter thus carried away by waters percolating through rocks should receive careful attention. The cementing substances of sandstones is frequently thus gradually removed and borne away chemically, while the grains of sand having no coherence among themselves in the situations longest exposed to this disintegrating action are carried off mechanically, the grains of sand and their cementing matter again forming solid rock under new conditions, though probably seldom again united in the same mass.

Atmospheric influences and the descent of rain water into rocks, even to depths where the water acquires a heat rendering it capable of effecting a solution of substances which could not have happened at comparatively low temperatures, thus cause the passage of soluble mineral matter from one place to another, cracks and other cavities being filled with different compounds, bearing various names, and becoming under favourable conditions crystallized. Hard rocks are decomposed in one place, and the matter which they have lost consolidates beds of loose materials in another, so that we may consider the compound parts of a large amount of rocks as silently and slowly moving from one place to another during the lapse of time, new dislocations of the surface of the earth, and the protrusion of igneous products of various kinds through that surface greatly aiding in the chemical change to which so many masses of rock are subjected.

Very important modifications of rocks must be effected by any covering of melted rocks flowing over them, particularly when such rocks are permeated by moisture; for then we have heat, water, and often the vapours of various kinds, the fruitful causes of many chemical changes, acting on them, sometimes giving to the rocks greater solidity, at others aiding their decomposition and disintegration.

We have seen that sandstones become decomposed from atmospheric

influences and the percolation of water, or rather the substances cementing the grains of sand together; for a large proportion of such grains do not readily suffer decomposition, but are again committed to running waters to be again gathered together in banks or beds. Renewed friction may render them somewhat smaller in many cases, but probably, as a whole, after a certain amount of trituration, no very material change is effected in this respect until after a long lapse of time and much grinding against each other, particularly when exposed on shores to the action of heavy breakers. It should be recollected, when considering this subject, that the less the size and weight of the grains, the easier they are mechanically suspended in water, and, therefore, the less are they exposed to the grinding and reducing action to which larger grains or pebbles are subjected when not removed from friction on each other by the same amount of movement in the water.

Not only have we sandstones thus decomposed and removed, but also a variety of slates, marls, and clays, forming matter more readily held in mechanical suspension, as well as hard gravels, either still loose and incoherent, or consolidated as conglomerates. To the former class of substances, easily held in mechanical suspension, we must add the decomposed felspars of a large portion of the igneous rocks, in some countries a matter of much importance chemically and mechanically, the silica and potash being removed by the former method dissolved in the water, while the silicate of alumina is mechanically transported and deposited as clay. This decomposition of the felspar usually disintegrates the rocks of which it forms a part, and quartz, mica, and other minerals, as the case may be, come under the mechanical influence of water, and are moved to new situations by it. Angular fragments are formed in abundance from the effect of atmospheric influences, especially in mountainous regions, and on the higher parts of sea cliffs.

According to the mountainous, hilly, or plain character of a country, is the fall of the drainage depressions and their general character, the ordinary rapidity of the brooks and rivers in them, and consequently the power of mechanically removing and transporting the mineral matter which is either worn away by these running waters, or which may be borne into them from the decomposed rocks adjacent. When the drainage is interrupted by cavities, the waters spreading out into lakes of adequate size, the detritus mechanically borne onward by the waters is arrested, and before a continuous line of running water can be formed the cavity must be filled up. A study of the entrance of running water into lakes soon shows how this is accomplished.

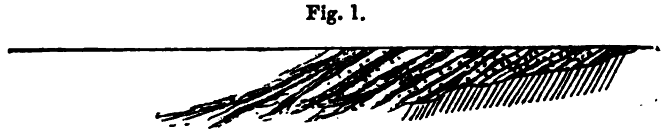
When committed to running water, the substances to be transported mechanically are moved in two ways. Should the particles be small, they are readily caught up in mechanical suspension, and carried for-

ward, especially in floods, when the rivers and brooks are swollen and a greater volume and weight of water press onward. Coming into the still waters of lakes, the whole is checked, and a deposit of the mechanically suspended matter is effected. This matter is usually such as to form mud or clay,—very small sandy grains, when the rivers have become particularly rapid and full, sometimes being sufficiently added to produce silt.

The movement of sands and gravels onwards by means of running waters is usually by forcing these substances along the bottom of the brooks and rivers,—as it were, sweeping them forwards. At times the same substances may be caught up, from considerable movements in the water, in mechanical suspension; at others, from diminished motion of the water, be merely swept on; and between the one action, according to conditions, and the other, there may be frequent changes; but as a whole the great mass of sand and gravel appears to be shoved onwards in rivers by the friction of the superincumbent water.

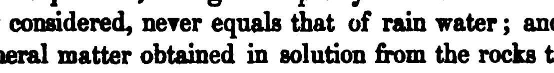
In great lakes ample opportunities are afforded for seeing the varied manner in which a cavity in the course of the general drainage of the land is being filled up; in one place, the shore being steep, sands and gravels are forced into them, and accumulated at high angles, as in Fig. 1;

Fig. 1.



in another, sands and clay are intermingled, as in Fig. 2; in more favourable localities, nearly horizontal beds of clay are formed, as also

Fig. 2.



of limestone from waters in which sufficient calcareous matter is held in solution, to be deposited when the causes of this solution have ceased.

With the exception of the evaporation from the waters when in the lakes, those flowing into them pass out free from mineral substances in mechanical suspension; though the purity of such out-flowing waters, chemically considered, never equals that of rain water; and thus some of the mineral matter obtained in solution from the rocks traversed by the water, even in cases where deposits of calcareous or other matter have been chemically formed in the lakes, escapes into the sea.

Arrived at the sea, the detrital matter is materially influenced in its distribution, according as the coast to which it is carried is either washed

by a tideless or a tidal sea, and to its relative amount of exposure to prevalent winds and breakers. In a tideless sea the effects produced would be similar to those in a lake. We may, indeed, consider such seas, as those of the Caspian, as mere saline lakes (whether portions of the ancient sea, detached by alterations in the relative levels of land and sea, or bodies of water rendered saline by reposing on saliferous rocks), in which not only the matters mechanically suspended and brought down by rivers into them are accumulated, but those in chemical solution also, inasmuch as such waters are only retained as they are by the evaporation of those so brought into them. Hence, in such isolated seas the river-borne saline additions should have an influence on the deposits formed in them.

The Mediterranean affords a good example of the varied accumulations which take place in tideless seas, for the Mediterranean may be so termed as regards the subject under consideration, as its coasts afford examples of both shallow and deep water immediately adjoining them, into which the matter brought by rivers, mechanically and chemically, is discharged.

When we regard the mouths of the great rivers which have flowed over much level ground, due in a great measure to the mud, sand, and gravel brought down by themselves, such as the Nile, the Po, and the Rhone, little else is discharged into the sea except finely comminuted matter. This, especially during floods, is carried bodily outwards; no small portion moving with the fresh waters over those of the sea, from the less specific gravity of the whole. The fine detritus eventually settles, and charts show us the form in which this is effected. The action of breakers prevents the accumulation of the muddy matter within their range, so that the accumulations in the immediate coast line become complicated. The river action, and the piling action of the breakers, combine to produce lines of sand, behind which accumulations of mud are effected, and these continue to be intermingled as the mouth of the river advances. Such is not the case with the detrital matter carried into the sea itself, beyond the action of the breakers. The sand forced forward on the bottom of the river will be more in flattened sheets, and nearest the mouth of the river, while the mud accumulates at a greater distance.

We may thus have three kinds of accumulations, one above the other, as the embouchures advance seaward. First and lowest, clay or mud, deposited at the greatest distance from the land, and inhabited by marine animals suited to such conditions, the thickness of the deposit depending on the original depth of bottom. Secondly; as the detrital accumulations of the river advanced, the clay or mud would become covered by the sand (mingled, perhaps, with some clay) forced over the

previous sea bottom, and inhabited by marine animals suited to the new arenaceous condition; and we might also expect to find the remains of estuary creatures occasionally in the sand. Above this second or sandy accumulation, the detrital matter getting above the surface of the sea, the results above mentioned, as arising from the united action of the breakers and the river, would be obtained. We should not expect a thick deposit of this kind, but during its progress there would probably be a mixture of estuary remains, even perhaps lacustrine, (isolated fresh-water lakes being formed amid the lagoons silting up,) with the marine shells, accumulated in the sands by the breakers. In shorter rivers, flowing into deep water, of which there are numerous examples on the coasts of the Mediterranean, and especially when such rivers are in flood, light detritus is borne outwards to settle in the deeper parts of the sea, fine sand even being so carried out in mechanical suspension; while the chief accumulations are formed of sand and pebbles, forced forward over the bottom of the river, and deposited, layer after layer, in a general diagonal form, the surface keeping, as a whole, horizontal. From changes in the direction of the river's mouth, or mouths, these accumulations take a complex form; so that a section made horizontally, a few feet from the surface, would possess somewhat of the following character,—one due to the varied protrusion of sands and

Fig. 3.

pebbles, according to the direction and force of the water acting on the loose materials; so that a vertical section of the accumulation would be much as represented in Figs. 4 and 5.

In these cases, also, during the advance of an embouchure, the sands and gravels could cover bottoms in which mud and clay had previously been formed by deposit from mechanical suspension being, as it were, swept over them.

We have only to suppose alterations in the relative levels of the sea and land, such as are now well known to have taken place, to have alternations of clays, sands, and gravels entombing the remains of

Fig. 4.

Fig. 5.

animal life suited to different conditions, the sands and gravels often forming extensive beds, with diagonal partings. When considering the power of transporting the finer sedimentary matter in mechanical suspension, we should recollect that in seas particles can be kept longer in mechanical suspension by a given motion of water than in fresh water, from the difference of the relative specific gravities of the two fluids; and, consequently, with the same amount of onward movement, that detritus can be carried greater distances by sea-waters, all other things being equal.*

With slight modification, detritus borne into lakes and tideless seas may be considered as accumulated in the same manner, though there may be differences arising from chemical causes; changes being effected in the seas, among the fine sedimentary matter, from the substances in solution, to which similar matter in lakes may not be exposed.

The deposits of sedimentary matter in tidal seas would so far differ from those in lakes and tideless seas that they would be modified by the action of tidal currents, by the greater amount of coast brought within the destructive action of the breakers, during the rise and fall of tides, and by the ponding back of rivers to various distances from their embouchures during flood tides, causing deposits of detritus in estuaries, and the discharge of the ebb-tide waters in particular directions.

The tidal wave becomes a power sweeping forward sedimentary matter along sea bottoms and estuaries, in proportion as the depths are shallow, and as there arises much friction on the bottom. In arms of

* The Rhone, at its entrance into the lake of Geneva, affords a good example of the manner in which the turbid waters of a river fall into a lake. Being specifically heavier with their usual load of detrital matter borne down by the glacier waters than those of the lake, volume after volume is seen to descend into the depths, and the surface remains clear while mud forms beneath, the turbid heavier waters forcing their way for a long distance under the still clear waters above, as is shown by soundings. In fact, the two waters resemble any two fluids of unequal density thrown into a basin together; and until the river water becomes lighter by the deposit of the matter held in mechanical suspension, it will tend to find its way over the bottom.

the sea and estuaries, which may be termed funnel-shaped, such, for instance, as the Bristol Channel, and the Severn at its termination, there are great sweeping powers of the waters, arising from the velocity produced by the mode in which the tidal wave is caused to act, so that the upper portions of such estuaries are kept constantly turbid by the finer detritus held in mechanical suspension. Instead, therefore, of such finer detritus being discharged readily seaward, as in tideless seas, it is deposited in the sheltered parts of these estuaries, where there is little movement in the water, filling up such places to the level that the sediment-bearing waters can cover. Consequently, in estuaries we often find the shores muddy and the central parts sandy, the friction and motion of the water preventing any mud accumulations in the latter.

The action of the tides has a tendency to flatten out the sedimentary matter, either arising from a deposit of the detritus held in mechanical suspension, or borne into tidal influences by the friction of moving water on yielding sandy or other bottoms. This action also would produce, by friction, those ridges and furrows so commonly seen beneath running waters, sandy tracts left dry at low tides, and upon blown sands. It will be readily understood that, upon a given locality, from the greater volume and velocity of the water during spring tides, such ridges and furrows could be then produced which could not be formed at the neap tides, from the absence of the adequate volume and velocity of moving water above these sea bottoms at that time.

While in tideless seas and great lakes the destructive action of the breakers keeps a horizontal line, varying but little, the detritus removed from the coast so acted upon travelling outwards but a slight distance into the still water adjoining, and the waves, from the movement of the water, may keep the finer detritus mechanically suspended along shore, there is greater destruction of the land on tidal coasts, and the tides become carriers and sweepers of the sand and mud thus brought within their influence.

On a tidal coast, as a whole, the breakers are heavier than on a tideless shore, from the more open and exposed character of the one than the other. Ground-swells, the heavy breakers from which are so destructive, are necessarily more common on the one than the other, these being little else than the waves produced, during heavy gales in the open oceans, rolling on the coasts, when such waves have originally been of sufficient magnitude to reach them. The friction and roar of the surf, as it is termed, is well known on some oceanic coasts to be ceaseless.

A slight study of any well-exposed oceanic coast is sufficient to show the effects of the degrading force of breakers. No doubt, here and there, it blocks up the mouths of valleys, damming up the free flow of the

drainage waters of the land, when these are not sufficiently powerful to contend with its piling influence, and it heaps up huge beaches, breaking upon the barriers which it has itself raised; but where the coast is fairly exposed, rising well above the sea level, no soft rock can stand before this power, and all such are ground away; many a patch of soft rocks above the action of the breakers attesting their once further range seaward.

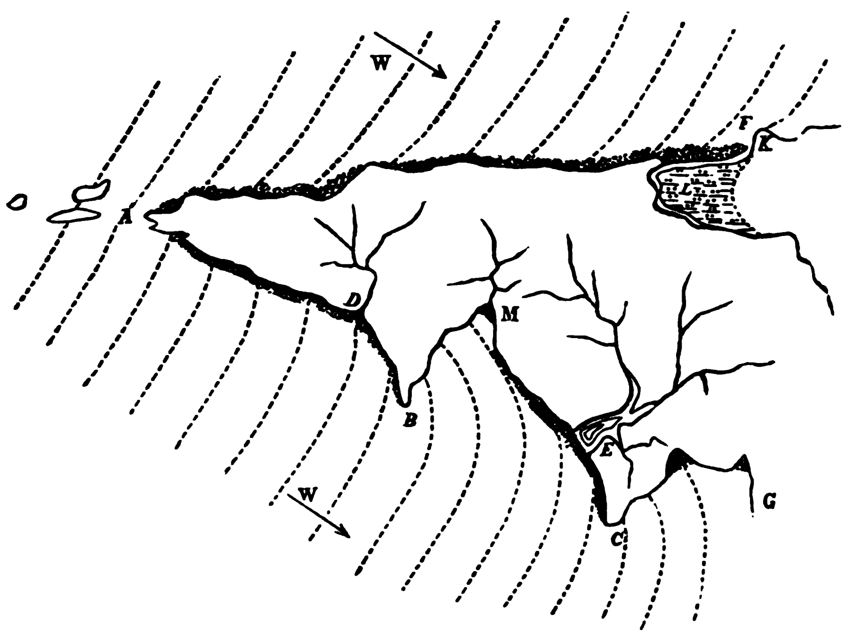
The rounded boulders and pebbles produced by this grinding action, many a fragment detached from the cliffs above by the influence of ordinary atmospheric causes being added to them, are necessarily moved in the direction of the prevailing force acting upon them. This will not be seaward, because the great power of breakers is coastward, driving all that they can either gather up in mechanical suspension, or carry on by friction, towards the land,—the return action of the breaker, unless it should have a cliff to strike against, and thereby rebound with great force, possessing less power than its fall forwards. A fact abundantly proved by the lines of shingle beaches in front of low lands.

Though not borne outwards, if there be any force acting upon them in the direction of the coast, more one way than another, the shingles will necessarily travel in conformity with it; and hence, where the prevalent winds, and, consequently, the lines of waves, fall obliquely on a coast, the shingles will strive to find a passage, or travel in the direction of the impulse given them. This is found to be strictly true; for although breakers may generally appear to adjust themselves to the tortuous character of a coast line, there is always a slight oblique action from the main direction of the wind at the time, if it be sufficiently powerful, producing waves.

The travelling of the shingles, thus produced, is modified or arrested by several circumstances, which the following figure (Fig. 6) may serve to explain. Let G, C, B, A, F, represent a line of coast exposed to the prevalent winds W.W., producing lines of waves and of action represented by the dotted lines at right angles to their direction. The shingles would strive to travel on one side from A to F, and, on the other, from A to G. On the former they could readily, but gradually, travel along shore until they arrived at the river F, supposed to be of sufficient size to keep its embouchure clear for a free passage of its waters. Here the river would interrupt the further progress of the shingle, and a struggle would commence between the action of the river endeavouring to turn the shingle back, and the action of the prevalent breakers forcing it forward. The results necessarily depend upon the general power of each action. Usually the breakers gain, so as to produce a long line of shingles, turning the course of the river, until the latter obtains support from a hard cliff, as at K, and is no longer forced aside. In

such cases the bank of shingles often accumulates, and behind, as at L, estuary deposits of mud and sand are effected.

Fig. 6.



In travelling from A to B, where we suppose, for illustration, a point of land jutting out into deep water, and a river at D, with water in it, in its ordinary state, not sufficient to contend with the piling influence of the breakers, the shingles would pass forward gradually to B, their progress being only interrupted for a short time by floods at D, during which there might be a free passage through the shingle barrier.

Arrived at B, the pebbles would no longer keep within the influence of the breakers to be forced onwards, and they would, as it were, be shovelled into the deep water, accumulating in a kind of heap, the gradual additions to which would indeed produce some effect in collecting a mass of shingle, resting on the base of the cliff under water.

In such cases we may have the broken remains of shells among the shingles within the influence of the breakers; while some of the same kind of animals which produced such shells, with other animals, may exist undisturbed amid the pebbles thus forced into the deep water; so that this continuous mass of pebbles would, if lifted above the sea, be found to contain broken shells in one place, and whole shells, some even such as Serpulæ, tending to cement the pebbles together, in another.

Supposing C to be another point of land advancing into deep water, the shingles obtained from the coast between M and C would be there arrested in their progress, as at B, in their course barring the mouth of a shallow sub-aqueous valley, considered to exist at E, the river waters falling into which were of insufficient volume to counteract the formation of a bar of shingles coming down from the direction of M. In such a condition of things, as in the Looe Pool in Cornwall, the bar would separate a fresh-water lake from the sea, the excess of the river waters percolating through the shingles seaward.*

A variety of modifications, not here noticed, will readily be conceived, and an examination of any extended line of coast will furnish abundant examples of them. The general result is an unequally distributed fringe of pebbles adjoining the coast, behind which there may be patches of mud and sand, sometimes containing the remains of estuary, at others of fresh water animals. Under very favourable conditions of position and of winds, causing the advance of pebbles, a mass of shingles may be collected, as at Dungeness, forming a continuous and nearly level bed, of considerable area.

Though, as regards the tideless seas and lakes, the prevalent winds also cause the breakers to drive shingle in the manner here described, the amount of pebbles produced is, as before noticed, smaller, and, from the generally inferior power of the breakers, less force is employed to propel them onwards. Nevertheless, they do often accumulate from this cause in considerable abundance, and effects of much geological importance are produced. The rise and fall of tide, however, combined with the generally greater power of the breakers, gives a driving force in the one case far more considerable than can be obtained in the other.

Sand is necessarily subjected to the same influences as the pebbles, and nothing is so well known as the removal of a mass of sandy beach from one place to another, as different winds, causing breakers to fall in one direction and then in another, act on a coast. The sand being somewhat readily caught up, however, in mechanical suspension after

* In such situations it sometimes happens that a great flood of waters from the interior will force a passage through the bar, so as to allow the sea water to flow in and out with the tides for a time, consequently driving away the fresh-water creatures which can escape, and introducing marine animals. When, from the blocking up of the passage, which generally happens during a gale of wind, the fresh-water lake is restored, all animals which cannot sustain the change are killed, so that deposits taking place during this time upon such areas may contain singular mixtures of fresh-water and marine remains. In the Looe Pool, which is let out by artificial means occasionally (*see* Report on the Geology of Cornwall, Devon, &c., p. 447), common sand shrimps (*Crangon vulgaris*) are numerous in the fresh-water lake, forming no small portion of the food of its celebrated trout. In the lake behind Slapton Sands, Devon, flounders are shut in with the trout.

the waves and, consequently, the breakers have attained a fair size, it is not unfrequently removed from exposed shores during gales of wind, and carried with the current of tide outwards, or thrown down in sheltered situations. More moderate weather with minor breakers usually heaves this sand back again, so that the general character of a coast remains as a whole the same. The steep slopes of shingle beaches often pass down beneath the sands, covering up their base, the sands heaped up or removed according to circumstances.

The piling action of breakers acting in shallow water on the one hand, and the checked motion of detritus-bearing rivers in flood, where they meet the sea, on the other, produce those accumulations of sand, across many tidal rivers, so well known as bars. A tidal river exercises its chief scouring action, forcing a passage and cutting through these bars by friction on the ebb tide, when the whole of the river waters, ponded back by the rise of the flood tide, pass out with the sea waters that have entered during the flood, the usual flow of the river still continuing to add to this mass of water flowing out seaward. The height of a bar is therefore an adjustment to these conditions; and any alteration in the volume of the combined sea and river waters passing out would produce its corresponding effect on the bar, the greatest effect being when a freshet or flood in the river is combined with a high spring tide, the volume of water and the velocity of its passage out being then the most considerable. If, therefore, an estuary or tidal river is filling up inside the bar, as the volume of sea water which can enter is decreased thereby, so is the power to cut down the bar diminished. As the bar rises, the power of the sand borne down by the river to escape becomes lessened, so that a large muddy and sandy accumulation succeeds to the area once occupied by tidal waters. The mouths of the river may indeed advance, but the same results will follow, and the detritus borne down by the river will accumulate. It is well known that large advances are in this way made in tidal seas, the current of tide making a more general distribution than on tideless seas, the great deposit still, however, moving onward and gradually filling up the sea before it.

In the discharge of estuary waters seaward, the waters of the ebb are necessarily carried in the direction in which that tide sets along any given shore. The rush of the river waters ceasing, the matter held in mechanical suspension will be deposited according to its volume and weight. The finer particles may be carried for a long distance, particularly when gales of wind keep the sea, into which the estuary waters have been discharged, in violent agitation. The same waters, charged with whatever may fall into them, are carried backwards and forwards by the tides; so that, looking at the average chances of deposit, there is

much opportunity for widely distributing the matter in mechanical suspension brought out from the rivers, a preponderance of some deposits occurring along the lines of the ebb tide. We can readily understand different areas partaking of characteristic deposits corresponding with the kinds of detritus borne down given rivers, so that though contemporaneous they may differ materially. At moderate depths the action of the tidal current would certainly tend to mingle them considerably, as it were shading them off into each other, so far, at least, as such currents extend: but it should be recollected that a tidal current flowing at three miles per hour would only cause any substance freely suspended in it to move backwards and forwards a distance of eighteen miles, where the ebb and flood are each six hours.

As the tide rises it flows up the estuaries, checking that immediate discharge of detritus that would have been otherwise effected; and on shallow coasts, such as the mouths of estuaries usually present, the breakers acting on a wide area also tend to force much of the detritus back. In such localities blown sands are necessarily abundant, the on-shore wind, particularly during heavy gales, drying the higher parts of the sands, the soonest and longest exposed to its influence, larger belts being also often only covered by water during spring tides, and exposed to drying influences during neap tides, and thus the sand is borne inland beyond the reach of the breakers.

We may regard the detritus around tidal coasts as brought under a great smoothing process, the mass of waters moving backwards and forwards, and the action of waves catching up mud or sand as the depths permit, and assisting in the general distribution over an uniform surface. The strongest tidal currents will hollow out minor depressions, where they can be felt, and therefore in the situations where the tidal wave is so impeded in one place as to be thrown with increased force on another. These situations are commonly off headlands, or amid the complication of banks at the mouths of rivers; when considered, however, with reference to sections having the same scale for height and distance, they are commonly very insignificant, and their importance, however great as respects navigation, very slight as regards geology.

This movement around lands washed by tidal seas would produce different effects according to depths; and where these were considerable, accumulations would be produced similar to those in deep tideless seas. The depths at which the friction may be sufficiently considerable, with a given velocity of surface water, to produce the ridges and furrows, commonly termed "ripple marks," is still matter of inquiry, and, considering its geological bearings, one of much interest, particularly when we compare the physical evidences of deposits having been effected in

given depths with the zoological evidences as to those depths afforded by the organic remains contained in such deposits.

The mode in which calcareous matter may be formed is one of great geological interest, and it may be desirable briefly to advert to the conditions under which this may be effected. Stalagmitical incrustations may, perhaps, be regarded as the commonest form in which the production of limestone is made apparent to us. Waters containing an abundance of bicarbonate of lime in solution, losing the carbonic acid which kept the lime thus dissolved, common carbonate of lime is thrown down, friable, compact, or crystalline, according to the quickness with which this is effected. In many situations considerable masses of limestone are thus formed. Many rivers, fed by springs charged with bicarbonate of lime flowing into lakes, may be the means of limestone accumulations in them. In like manner rivers of the same character, discharged into tideless seas, may be considered as affording materials in the quiet depths of such seas for the production of limestone. Similarly charged waters would, however, be differently circumstanced in tidal seas, for the movements produced by the tides would prevent that quiet deposit which we can readily conceive to be affected in nearly still waters, merely agitated on the surface, or slightly moved in some situations by currents formed by the friction of the winds upon the sea. It is not difficult to conceive that on some coasts of tideless seas a large amount of calcareous matter may become accumulated after the lapse of ages, from the constant additions of water, containing much bicarbonate of lime, falling into a limited area, more particularly in situations where the agitation of the surface waves can be little felt.

The enormous mass of carbonate of lime forming or entering into the composition of the harder parts of so many animals, and which geology teaches us it has so done from the earliest periods, probably since life was first called into existence upon our planet, must have been in solution before it could have been appropriated to the purposes for which it was required. Land animals obtain it, with other requisites for their harder parts, either from plants or from water, the former having extracted it from the soil, and the latter in its passage through or among calcareous matter, the strictly carnivorous creatures getting it through the herbivorous. The same modes of appropriating the carbonate of lime prevail probably among fresh-water and marine animals, but among these classes there is reason to conclude that much of it is directly obtained from the aqueous medium by which they are surrounded, constant additions of calcareous matter being made to the lakes and seas by rivers which bring it down in solution.

Coral reefs afford striking instances of masses of carbonate of lime obtained through the medium of animal life, this substance having been

chiefly, if not altogether, extracted by the stone-making polyps from the adjacent water. There seems good reason for believing that there are very great beds of the shells of molluscs in many places, forming scarcely less important accumulations of the matter of limestone. Some oceanic islands to which the drift of common mud and sand cannot get, seem composed of little else than the calcareous matter which has once formed the harder parts of animals, such, for instance, as the Bermudas.*

In situations where calcareous matter is thus accumulating it is not difficult to see that the carbonic acid produced by the decomposition of the animal matter, in those cases where the animals perish naturally and are not eaten, but left to decompose, would, when confined in cavities, such as are common in a coral reef, act upon the carbonate of lime formed by the animals, thus furnishing the substance needful for its solution and which may be readily again driven off, allowing a purely chemical deposit of carbonate of lime to be effected, either in the cavities of such coral reefs or in adjacent situations, and connecting in one mass carbonate of lime, in forms such as it was produced through the agency of animal life, with carbonate of lime obtained by ordinary chemical means.

On some oceanic coasts the sands consist, to a very great extent of pounded and broken shells, so that these sands, often employed on our own coasts for agricultural purposes, sometimes contain 70 per cent. of carbonate of lime. When driven on shore, as they sometimes are, by the united action of the sea and wind, they are well known to become consolidated as we should expect they would be, atmospheric water, sometimes percolating among vegetation, dissolving enough of the grains to cement the mass together. So firm is the resulting rock, that when a mass of it is struck, pebbles of quartz will sometimes be divided by a blow in the middle of this consolidated sand.

Where such sands are found on the shores we expect and usually find the adjacent sea bottoms composed of the same materials, which are nothing more than the remains of multitudes of molluscs and other marine animals having harder parts composed of carbonate of lime, to which the animals living in and upon these remains will again make additions.

From deposits and accumulations of the kinds mentioned, greater or less areas can be covered by nearly pure calcareous matter, and some of them may be mixed in many a comparatively tranquil situation with ordinary mud or clay; also finding rest from mechanical suspension in

* A very valuable and interesting account of the geological structure of the Bermudas is given by Lieutenant Nelson, of the Royal Engineers, in Vol. V., Second Series, of the Transactions of the Geological Society of London. Most of the facts therein noticed are of great value, when we compare the limestones of various geological dates with the limestone formations of the present day.

water in a similar locality. We can readily conceive that carbonate of lime chemically deposited may get very intimately mingled with mud, so that the whole may be more or less calcareous. If in such situations there be any alternation of causes, such, for instance, as a river or rivers at one time bearing down bicarbonate of lime in clear streams, and at others, when in flood, transporting fine detritus, there might be different deposits, forming alternate layers of limestone and clay. Occasionally, from the tendency to separate, we should expect nodules of limestone to be formed in layers, particles of the fine mud in all cases being much intermingled with the calcareous portions.

Ordinary oceanic or sea currents, as distinguished from those produced by tidal action, though chiefly due to surface causes, such as the effect of prevalent winds, sometimes produce sets of water in given directions that may considerably affect the distribution of detrital matter brought within their influence. In the Gulf Stream we possess a marked instance of a powerful current caused by the Atlantic water, driven westward and pent up in the Gulf of Mexico, escaping to the northward. Where great rivers, such as the Amazon, discharge themselves into these moving masses of water, a distribution of the finer detritus borne seaward must be produced in accordance with the general line of movement.

It is interesting to consider the modification of deposit which may be effected along such a sea line as that of the eastern coasts of America from Cape Horn to Baffin's Bay. From Terra del Fuego, excepting the Straits of Magellan, to the West Indian Islands, we have an oceanic coast under the action of tides, to which detritus from the interior is variously borne by the drainage waters. In the Gulf of Mexico and the adjoining West Indian Seas we have, as regards the distribution of detritus, a tideless sea communicating with the tidal coasts of North America by the strong current of the Gulf Stream. In the Bay of Fundy there is a good example of a great rise and fall of tide, caused by local circumstances producing corresponding effects, the resulting distribution and accumulation of mud, sand and gravel mingling gradually with those arising from the different rise and fall obtained on the other side of the neck of land connecting Nova Scotia with New Brunswick. The gulf and river of St. Lawrence present us with other conditions, and Baffin's and Hudson's Bays with others. On this coast, therefore, one extending many thousand miles, we expect a great variety of contemporaneous deposits, both as regards organic contents and mineral structure, due to a variety of conditions, the whole highly instructive when we examine and connect in great groups varieties of rocks formed at equal geological times.

Having thus sketched some of the modes in which mineral matter is

known or may be inferred to be now accumulated, we shall proceed to examine the probable manner in which the rocks of the district under consideration have been formed, taking them in their order of geological age.

Silurian Rocks.

As it would be premature to enter upon a general view of the probable mode in which the great mass of rocks, of older geological date than the Old Red Sandstone epoch, was accumulated in Wales, and in some of the neighbouring English counties, until the whole of that area had been carefully examined during the progress of the Geological Survey, the Silurian rocks which appear on the southern portions of Pembrokeshire, ranging thence by Caermarthen, Llandilo, Llangadock, and Llanwrtyd to Builth, with the outstanding and protruded patches of Malvern, Woolhope, May Hill, and Uske, will, for the present, be alone considered, and rather for the purpose of showing the kind of sedimentary deposits which immediately preceded those of the Old Red Sandstone, than as properly entering upon the accumulations of the older palæozoic rocks themselves.

As most nearly approximating to the district which has chiefly afforded Mr. Murchison the types of the Silurian System, exclusive of the Llandilo flags, it may be convenient first briefly to notice the Silurian rocks of Malvern, as they afford us evidence of the accumulations constituting these rocks having been continued beneath the intervening Old Red Sandstone, from the Shropshire districts, with but slight modification, in this direction,—in fact, showing that similar physical causes had affected the distribution of detrital and calcareous matter over the sea bottom of that old geological period for that distance; the mud, sand, and gravel banks, as the case might be, having been continuous from one locality to the other.

Referring to the Memoir* of Professor John Phillips for the needful detail of the Malvern Silurian rocks, the following general section, corresponding with that given in the Survey Vertical Sections, No. 15, will suffice for this sketch:—

Malvern Silurians.

	Feet.
1. White yellow, and brown sandstones, with partings of shale . . .	100
2. Gray shaly sandstones and thin shales	200
(*Upper Ludlow Rocks.*)	
3. Subcalcareous nodular rock in massive beds.	40
(*Aymestry Limestone.*)	
4. Gray shales, enclosing toward the lower part many bands of calcareous nodules	700
(*Lower Ludlow Rock.*)	

* Inserted next in order to this Memoir.

	Feet.
5. Limestones, in one, two, or three thick bands, according to the locality, alternating with shales and bands of calcareous nodules	240
(*Wenlock Limestone.*)	
6. Gray argillaceous shales, with a few small bands of calcareous nodules	640
(*Wenlock Shales.*)	
7. Rough subcalcareous rock	20
(*Woolhope Limestone.*)	
8. Shales and thin sandstones, with a few thin bands of limestone	80
9. { Sandstones and shales in frequent alternations	240
Sandstones of a gray tint, overlaying and alternating with others of a purplish brown, or deep purple. Both locally conglomeritic and sometimes mixed with trappean ashes, and of a remarkably dry cracked aspect }	690
(*Caradoc Sandstone.*)	
Irregularly interposed trap.	
10. Black shales, with a few thin and hard sandy bands, and layers of trappean ashy sandstone	500
(*Upper Llandilo Series.*)	
11. Greenish sandstones in thick and thin beds, often of a trappean aspect, and traversed by a few trappean dykes	uncertain, at least 600

We here obtain a section of somewhat more than 4000 feet of Silurian rocks, showing accumulations under different conditions, the extent and modifications of which may be seen by the following sections at Woolhope, May Hill, Uske, Builth, Llangadock, and Llandilo, near which latter place the Old Red Sandstone overlaps the Silurian rocks in a manner to be noticed hereafter.

Woolhope Silurians.

	Feet.
1. White, yellow, and brown sandstones	80
2. Gray shaly sandstones and thin shales	90
(*Upper Ludlow Rocks.*)	
3. { *a* Gray shales enclosing thin beds of limestone	45
b Subcalcareous rock in massive beds, full of nodules	40
c Shales and thin beds of limestone }	40
(*Aymestry Limestone.*)	
4. Gray shales, generally soft, enclosing, towards the lower part, many bands of subcalcareous nodules	660
(*Lower Ludlow Rocks.*)	
5. { *a* Beds of massive limestone, somewhat nodular	50
b Nodular limestone, alternating with beds of shale	50
c Limestone in massive beds of various hues }	50
(*Wenlock Limestone.*)	
6. Gray argillaceous shales, generally soft, enclosing many bands of small subcalcareous nodules towards the lower part	1100
(*Wenlock Shales.*)	
7. Gray and blue limestone in many beds, alternating with thin shales	120
(*Woolhope Limestone.*)	
8. Shales and thin sandstones, with two or three thin calcareous beds	90
9. Sandstone in thin beds, alternating with thin beds of shales, resting upon sandstone in thicker beds—thickness not seen	180
(*Caradoc Sandstone.*)	

May Hill Silurians.

	Feet.
1. White and yellowish sandstone	70
2. Thin bedded sandstones, with thin beds of shales	100
3. Thin beds of calcareous sandstone, and nodular limestone and shale	50
4. Shales, with calcareous nodules, at ninety feet (descending), a bed of fossil corals	140
5. *a* Red dolomitic limestone	25
5. *b* Shales, with numerous beds of nodular limestone	275
5. *c* Gray or blue limestone in massive beds	40
(*Wenlock Limestone.*)	
6. Shales, with a few beds of calcareous nodules	1000
(*Wenlock Shales.*)	
7. Numerous beds of limestone and shale	240
(*Woolhope Limestone.*)	
8. Shale, with a few thin bands of nodular limestone	140
9. Sandstone and thin beds of shale, resting on sandstone, with some conglomerate and occasional beds of shale	300
(*Caradoc Sandstone.*)	

Uske Silurians.

2. Shaly, and micaceous sandstones, lower part calcareous	120
(*Upper Ludlow Rocks.*)	
3. Thinly laminated calcareous beds	20
(*Aymestry Limestone.*)	
4. Gray shale, calcareous towards the base	190
(*Lower Ludlow Rocks.*)	
5. Massive limestone, with shale partings	120
(*Wenlock Limestone.*)	
6. *a* Hard blue calcareous shale, containing bands of blue limestone, about one inch thick, 40 feet; *b* Shales, less calcareous, 20 feet; *c* Argillaceous and arenaceous shale in thick beds, 40 feet; *d* Sandy shales, 200 feet	300
(*Wenlock Shales.*)	
7. Massive limestone, nodular at top	130
(*Woolhope Limestone.*)	
8. *a* Shales, sometimes hard and micaceous, with patches of nodular limestone, 70 feet; *b* Limestone, 30 feet	100
9. Sandstones, commonly in thin beds, alternating with shales, the former predominating	110
(*Caradoc Sandstone.*)	
10. Shales, with three or four bands of sandstone, 110 feet; Shales, with two thin limestone bands towards the lower part, 370 feet	480
(*Upper Llandilo Series.*)	

Builth Silurians.

1. Very micaceous sandstone, fossiliferous, replete with organic remains, (tilestone.) [These beds are observable near Cwm-Craig-ddu, but near Builth they seem to become associated with red marls and cornstones.]	
2. Thin bedded and gray, fine grained and fossiliferous sandstones, sometimes slightly calcareous and frequently micaceous, measured at an excellent section at Cwm-Craig-ddu	3168

3. Thin and interrupted band of limestone, composed of little else than the remains of *Pentamerus Knightii.*

(*Aymestry Limestone.*)

		Feet.
4.	*a* Argillo-arenaceous rocks, with much oblique bedding and other evidence of irregular accumulation. Many of the beds are arranged in large irregular concretions	210
	b Thin limestone beds	10
	c Same rocks as at *a*	300

(*Lower Ludlow Rocks.*)

5. Nodules and interrupted beds of limestone 10

(*Wenlock Limestone.*)

6.	*a* Argillaceous shale and slate, with numerous argillaceous limestone nodules	550
	b Argillo-arenaceous rock; beds of irregular concretionary structure; concretions often many feet in diameter; beds sometimes calcareous; much general resemblance to *a* and *c*, No. 4	250
	c Argillaceous shale and slate, with nodules and beds of limestone, as at *a*, the nodules and limestone decreasing downwards	750

(*Wenlock Shales.*)

10. Argillaceous shales, dark, on the upper part, very black in the lower, with *Asaphus Buchii, Trinucleus fimbriatus, T. Lloydii.*

(*Upper Llandilo Series.*)

11. Argillo-arenaceous beds and sandstones, containing *Asaphus Buchii, Trinucleus fimbriatus, &c.* 400

(The equivalents to this, westward from Builth, have conglomerates mingled with them.

12. Black shales, with *Asaphus Buchii, Graptolites, &c.*

In this part of the section, in the range of the Carneddau, there is much intermixture of trappean ash, sandstones, and flat trappean beds, some vesicular,—a local accumulation, which does not appear among the equivalent beds upraised to the westward of the same range towards Rhayader.

Section of the Silurian Rocks upon the Sawdde near Llangadock, Caermarthenshire.

		Feet.
1.	Gray laminated and micaceous sandstones, *fossiliferous*	390
	Sandstones, hard and soft, with some marls, nearly the whole red . .	600
2.	Purple and red conglomerate and sandstone	65
	Purple and red sandstone and conglomerate, with micaceous bands, *fossiliferous*	40
	Purplish gray, hard, thin micaceous sandstone	40
	Similar beds, with gray shale partings, *fossiliferous*	130
	Similar beds, with green shale partings, *fossiliferous*	200
	Line of red conglomerate.	
4.	*a* Very thin argillaceous sandstones, 130 feet	1570
	b The same, with partings full of fossils, 440 feet	
	c Thin bedded sandstones, with shaly partings and some fossils, 1000 feet	
6.	Argillaceous shales, with thin beds of sandstones.	170
	Same series, the beds of sandstones thicker.	360
	Thick and thin bedded sandstones, with a few fossils	180
10.	Argillaceous shales. (*Asaphus Buchii, Trinucleus fimbriatus, &c.*) .	300
	Limestones, with argillaceous shales. (*Asaphus Buchii, &c.*) . .	240
	Argillaceous and arenaceous shales	300
	Trappean ash, containing *Asaphus Buchii, &c.*, and trap	200
11.	Hard sandstone, with some conglomerate	300
12.	Black shales with limestones—thickness not seen.	

Llandilo Silurians.

		Feet.
1.	Gray laminated sandstone, micaceous, in beds of various thickness.	140
	Gray laminated and argillaceous sandstone in thin beds	47
	Gray laminated sandstone, light coloured and micaceous	160
	Laminated blue shale	6
	Conglomerate beds with fossils, graduating into	60
	Light-coloured sandstones	220
2.	Hard gray sandstones	60
	Arenaceous shales and thin laminated sandstones, with bands of fossils	430
	Sandstone in thick and thin beds, partly micaceous and shaly, with lines of fossils, the lower part light-coloured, sandstones in thick beds	380
	Thick bedded sandstones and arenaceous shales	60
4 & 6.	Thin laminated sandstones, with thin partings of arenaceous shales, the sandstones prevailing in the upper part, and the lower gradually becoming more argillaceous	1360
	Coarse and somewhat conglomeritic sandstones, in irregular beds, with thin partings of sandy shales and lines of fossils	300
	Arenaceous shales with thin laminated sandstones growing more argillaceous downwards	480
10.	Argillaceous shale generally laminated; in parts much indurated, and in parts acquiring a nodular character	260
	Sandstones and indurated shales more or less calcareous	300
	Argillaceous shale, thinly and irregularly laminated, with a few highly indurated bands, and some nodular structure. (*Asaphus Buchii, &c.*)	1330
11.	Sandstones, most frequently coarse-grained	320
12.	Argillaceous shales, with flagstones and limestones—thickness not seen, but estimated more than 1500 feet.	

(*Lower Llandilo Series.*)

Proceeding westward, beyond the last section, the overlap of the Old Red Sandstone becomes such that from near Middleton Hall to the vicinity of Caermarthen, it rests on the lower Silurian rocks, covering up the higher Silurian beds; indeed, near Pound, the sandstones of the Llangadock and Llandilo sections, marked 11, seem in close contact with the Old Red Sandstone. At Lampeter-Velfry, the limestones of the Llandilo flag series are not far removed from the Old Red Sandstone, and the overlap continues to Slebech, where in its turn the Old Red Sandstone is overlapped by the carboniferous or mountain limestone, which, near Haverfordwest, is again overlapped by the coal measures, the latter thus resting, in that vicinity, upon the lower Silurian rocks, the upper Silurian rocks, the Old Red Sandstone, and the carboniferous limestone being covered over, as reference to the accompanying map, pl. 1, will show.

Though this overlap may appear considerable when we regard the thickness of the beds observed at the western part of Caermarthenshire, it is really very gradual viewed as a whole; so much so, that where the beds are disturbed, or elevated, at considerable angles near the junction of the rocks, the unconformable relation of one set of beds to the other is only apparent on the great scale, and by embracing a considerable area.

The Silurian rocks in their range westward, near Caermarthen, disclose the following section beneath the Old Red Sandstone:—

		Feet.
10.	Gray shales, about	300
	Shales mingled with some sandstones	900
11.	Conglomerates and sandstones	1000
12.	Shales and sandstones	600
	Dark shales, with some sandstones	1800
	Black shales, at least	900

Near Lampeter-Velfry, and on the northward of the village, the following succession is observed, not so well exhibited, from the disturbed condition of the beds, towards the Old Red Sandstone on the south.

		Feet.
11.	Sandstone and conglomerate	120
	Gray arenaceous shales, with many bands of fossils	900
12.	Black shales with graptolites	150
	Limestone with shales	360
	Black shales, at least	900

Sections of a generally similar order are obtained thence by Robeston Wathon, toward Haverfordwest, where the coal measures rest upon sandstones and arenaceous shales, prolonged from those noticed in the section above, and well shown near the gas-works at Haverfordwest, where bands of organic remains are found among them.

Though from the disturbed condition of all the rocks in southern Pembrokeshire, and their subsequent denudation, patches of Silurians are seen emerging from beneath the Old Red Sandstone between Talbenny and Walwyn Castle, extending from the latter to Rosemarket and Langwm, at Orlandon and Hooton, and between Freshwater West and St. Petrox, and from Highgate, near Orielton, to Freshwater East; the sections in Marloes Bay, and from Gateholme Island to Wooltack Park, and Musclewick Bay, are alone those which exhibit any considerable sequence of beds, the other localities being, however, important as illustrating the overlap of the Old Red Sandstone, higher beds being exposed by the openings thus affected through the Old Red Sandstone to the subjacent Silurians than are found to the northward. We thus find, judging from the organic remains contained in them, higher beds of the series at Freshwater East, than at Marloes Bay, and at the latter, than at Rosemarket, precisely as we should expect would be the case from the character of the overlap.

By a glance at the map, the Silurian rocks will be seen to pass round behind the point composed of Old Red Sandstone opposite Gateholme Island, so that we obtain the two following sections of beds of the same age, one in Marloes Bay, the other between the point and Wooltack Park.

Section from West Dale Point to the Trap in Marloes Bay.

Red Sandstone Series (part of the Old Red Sandstone)—0 to 276 6

		Feet.	Totals.
Red sandstone, hard and soft		9	
Red sandstone, hard, coarse grained	6		
Ditto with quartz veins	12		
Ditto pebbly	18		
	—	36	45
Red sandstones and marls		6	
Hard red sandstones, with white spots		24	75
Marly series with sandstones (obscurely seen)		129	204
Alternating soft red sandstone and thin gray beds		32	
Gray beds	5		
Red sandstone	7	17	
Gray beds	5		
Red sandstone, partly marly and cellular, the lower part of the bed is gray		10 6	
Red and partly gray sandstone	5		
Red sandstone	4	13 0	
Red and gray striped sandstone	4	——	276 6

Gray Sandstone Series (Silurian) 0 to 1657.

		Feet.	Totals.
Thin bands of micaceous gray sandstone		6 0	
Brown red sandstone		3 0	
Thin bands of micaceous gray sandstone		4 6	
Irregular gray micaceous sandstone		7 0	
Thin bands of micaceous gray sandstones		73 0	
		——	93 6
Soft gray sandstone, with small black nodules		10 0	
Hard irregular gray micaceous sandstone		6 0	
Soft bluish gray sandstone, with black nodules		40 6	
Ditto but harder		18 0	
Soft bluish gray sandstone, with black nodules		26 0	
		——	194 0
Hard gray sandstone	8 0		
Soft ditto	2 6	44	238 0
Hard gray sandstone	33 6		
Soft bluish shaly sandstones and sandy shales		57	295
Light-coloured shaly sandstones, stained with carbonate of iron and manganese		24	319
Fossil band, 2 inches.			
Purplish and reddish sandstones		73	392
Purplish gray sandstone		120	512
Hard gray sandstone, with two *fossil bands*, 3 inches thick		24	536
Bluish gray shaly sandstones, with many *fossil bands*		124	660
Harder gray shaly sandstones, with many *fossil bands*		38	698
Bluish gray shaly sandstone, *fossil band* at bottom		37	735
Hard gray sandstone; in the middle are black spots, near the bottom a *fossil band*		30	
Shaly sandstones, with *fossil bands*		41	
Ditto in a fallen cliff; the shales partly calcareous and *fossiliferous*		60	866

Coralliferous Series.

		Feet.	Totals.
Bluish gray shales, with numerous very thin bands of *coralliferous limestones*		293	1159

		Feet.	Totals.
Gray conglomerate, with quartz pebbles		6	1165
Pyritiferous shales, with sandy layers		12	

Fault in Cliff.

			Feet.	Totals.
Blue shales.	Hard Bed	0 9	2 9	
	Purplish shale	2 0		
	Blue shales and limestone bands and nodules		150 3	
				1330

Sandy Conglomerates and Pyritiferous Shales, alternating: viz.,

		Feet.	Totals.
Shales	24		
Conglomerates	2		
Shales	3		
Conglomerates	2		
Shales	3		
Conglomerates	4½		
Shale	1		
Conglomerates	2½		
		42	1372
Coarse bluish shales, with black *Lingulæ* and large shells		7	
Hard gray sandstones and bluish shales		19	
			1398
Sandstone and conglomerate		2 0	
Coarse gray conglomerate, with fragments of quartz and shale		30 0	
Finer conglomerates, resting on a band of coarser		12 0	
			1442
Shaly sandstone and arenaceous shale, very blue at the top		11 0	
			1453
Coarse sandstone		4	
Coarse shaly and pebbly conglomerate		7	
Shaly conglomerate		6½	
Sandstone and pyritiferous shale		6	
Coarse irregular quartzose conglomerate		36½	
			1513
Thin bedded sandstone		4	
Arenaceous shales and thin sandstones		15	
Light-coloured sandstone, stained with carbonate of iron and manganese, a *fossil line* on the top		30	
White conglomerate		1	
White sandstones		12	
Hard gray sandstone		42	
			1617
Great conglomerate mass		40	1657

Trap.

Section from Gateholme Island northwards towards Wooltack Park.

(Old Red Sandstone.)

	Feet.	Totals.
Red sandstone, partly marly and cellular	16	16
Hard sandstone, partly conglomeritic, and mostly grayish or brownish with quartz veins	60	76
Red and gray sandstones	30	106
Red and yellowish sandy beds	7	113
Series of hard brown red sandstones with softer red sandstones	227	340

West Dale Section begins here.

	Feet.	Totals.
Series of hard quartzose sandstones with interspersed soft red sandstones	52	392
Soft red marly sandstones with thin red sandy marls and some cornstone	25	417
Hard and soft red sandstones	59	476
(Fault 12 feet, throw allowed for.)		
Red and white sandstones	29	
Irregular grit bed	2	
Red marly sandstones, a little cornstone and white bands	28	
Red sandstone with quartz veins	22	
White marls	3	
Red marly sandstones spotted with white	25	
		585

(Fault here, throw west side forwards 55 feet, ranges north and south, allowed for.)

(Silurian Rocks.)

Gray Sandstone Series . . 0 to 2072

Gray sandstone	46	46
Gray shale and sandstone, some *fossil lines*	77	123
Gray sandstone	4	127
Gray shale and sandstone	40	167
Red partings	2	169
Subcalcareous gray shales	15	184
Hard gray sandstone and quartz veins	12	196
Shales and sandstones, subcalcareous with *fossil bands*, and veins of calcareous spar	89	285
Light gray shales	12	
Hard sandstone with quartz veins	18	
Light gray shales	13	
		328
Hard sandstones and shales	113	441
Hard sandstones, principally, to a bed where *fossils* occur	407	549
Hard sandstones and shales	563	1112
Blue shales with many calcareous thin laminæ. Shells rather numerous	300	1412
Hard sandstone and shale	331	1743
Fossiliferous shales with some sandstones to the Wall corner of Wooltack Park	329	2072

Trap and conglomerate below, and with them shales.

Fortunately to complete both these sections, cut off by the trap in Marloes Bay and at Wooltack Park, we find dark and black shales, with (near the upper part) calcareous, and even limestone beds, which, there can be little doubt, from analogies in the adjacent district occur beneath the beds enumerated above, at the Black Head, in Musclewick Bay. The coast thence to the south, affords an excellent section of these beds; the Head presenting a beautiful example of cleavage traversing them.

When we compare these various sections of the Silurian rocks, we find, employing terms suited to their original conditions, that a considerable accumulation of mud or clay, very frequently black, extended

nearly 140 miles in an eastern and western direction, for there is much reason for considering the black shales of the Malvern section as on the same geological parallel with the shales beneath the Caradoc sandstone at Uske, the dark and black shales, No. 10, at Builth, the argillaceous shales, No. 10, near Llangadock, and with the similar beds at Llandilo, and their continuation westward, terminating with shales above the conglomerates of the Marloes Bay section, St. Bride's Bay, Pembrokeshire.

In the Malvern sections, this clay or mud, mingled with bands of sands and trappean ash, rested upon sands and gravels, also containing trappean ash, at least 600 feet thick. No other of the sections above given, extend so deep in the series until we arrive at Builth, where we find gravels and sands in a similar position, and among them also trappean ash. The thickness of these sands and gravels varies most materially. Once, however, secure, in the Builth sections, of the position of these gravels and sands, there is no difficulty in tracing them westward. At Dol-Van, between Builth and Rhayader, they emerge from their covering of slates and shales (Wenlock shales), and can be readily followed by the Garth, near Llangammarch, to the Noeth-Grug, where they attain a very considerable local thickness, one of about 1000 feet. They are again in much force at Carngoch, Carregcegin, and other places near Llangadock and Llandilo (the conglomerates and sandstones, No. 11, of those sections), and occur also in considerable abundance on the southern side of the Towey, between Llanarthney and Caermarthen.

It may be here observed, that although it is desirable to leave the full detail of the rocks to the northward of the Towey, until a general description of the older rocks of Wales shall be given, the same conglomerates and sandstones are very abundant in the range of country on the right bank of the Towey, stretching to and beyond Llanwrtyd, and joining the district above mentioned westward of Builth. They are brought in and out, as contortions have been effected, and the beds are removed, or remain, according to the action of the denuding causes to which this district has been subjected.

From Pen-y-Moelfre, where these conglomerates and sandstones are exposed on the south-west of Caermarthen, the increasing overlap of the old red sandstone much embarrasses a clear view of the continuation of many associated accumulations westward. They would, however, appear to diminish in force in their range to the northward of Caermarthen, at Berllan and Cwmfelin, near Langan, and are not prolonged in the direction of Llandysilio, Llan-y-cefn, and other localities in that line of country. We may, however, consider the conglomerates of the high ground immediately northward of Llandewy-Velfrey, stretching

thence by Robeston Wathon, towards Haverfordwest, as the probable continuation of the conglomerates of Berllan and Cwmfelin, and as being represented in the Marloes Bay section by the conglomerates there mentioned.

It is worthy of remark, that among these sandstones and conglomerates, trappean ash is by no means unfrequent, a circumstance of much interest when we consider the area they occupy.

At Llangadock, Llandilo, and near Caermarthen, we descend still deeper into the Silurian series of Mr. Murchison, reaching those beds which he has more particularly named Llandilo flags, the result, apparently, of an intermixture of layers of mud, sand, and silt, with calcareous matter, silt and black mud not having been uncommon.

Considering these lower beds as a whole, fine sedimentary matter, capable, for the most part, of having been mechanically suspended in water, is the chief substance of which they are composed. Limestones have been formed somewhat locally. Of all the sections seen, the vicinities of Llandilo and Lampeter-Velfrey are those where they have been chiefly produced. When examined, though corals are not unfrequent in some places, and shells in others, much of the limestone appears chemically deposited from water, in some localities having been considerably intermixed with black mud; where the per centage of carbonate of lime has been small, as at Sholes-Hook for example, near Haverfordwest, insufficient to produce limestone beds, and in several other localities, even intermingled with limestones themselves, the upper portions exposed to the action of atmospheric influences have frequently suffered complete loss of calcareous matter, so that without studying quarries, or other fresh artificial cuttings, the true character of the deposit will not be seen.

In such situations, there is reason to conclude that the calcareous matter was disseminated through the mud or clay, and that it was borne in chemical solution, in the same waters, with the fine detritus mechanically suspended, as must often happen at the present day.

The limestones proper may be considered as very subordinate to the great clay or mud deposit of the Llandilo flag series, and the silty origin of many of the beds as subordinate also.

A considerable amount of tranquillity seems requisite for these deposits, at least so far as we have here noticed them. Should they have been formed in deep water, there was a filling up, or a raising of the bottom upon which the conglomerates and sandstones, noticed above, were accumulated; for the forces capable of transporting the pebbles and grains of which they are composed, were necessarily greater than those required for the finer sedimentary matter. Taking the lower rocks noticed in the Malvern section to be equivalent to these con-

glomerates and sandstones westward, the change, for the distance of about 100 miles, was so far general, marking an altered condition of the moving power. There is much intermingling of the sandstones, conglomerates, and shales, or slates, in some localities, pointing to there having been very local and minor accumulations of gravel and sand, strewed over a muddy or clay bottom. When we consider the conditions under which gravel and sands are now intermingled in a somewhat similar manner, shallow water seems required for the accumulation of these conglomerates and sandstones, and their mode of occurrence is frequently such as to remind us of the shoving or forcing action of gravel over the bottom, perhaps even of beaches. To account for the black mud accumulated upon these sandstones and conglomerates, the sinking of the area between Malvern and St. Bride's Bay, in which matter, mechanically suspended, was chiefly thrown down, seems needed, in certain localities, as near Llangadock and Llandilo, limestones of the kind noticed previously being formed.

The beds mentioned, may be considered as the Llandilo flag series of Mr. Murchison, the sandstones and conglomerates dividing it into two portions, which for present convenience may be termed upper and lower. The *Asaphus Buchii* inhabited the mud bottoms from Pembrokeshire to Builth, and it must have existed by myriads in some localities, such as at Llandilo and Builth, so that its remains, with the mud or silt, constituted accumulations of considerable thickness. The remains of the same trilobite are found in trappean ash, near Tan-yr-Allt, Llangadock, and in sandstone at Tan-y-graig, near Builth. *Trinucleus fimbriatus* and *T. Lloydii* appear to have been common, and in some places abundant inhabitants of the seas of the upper mud or clay, with graptolites in myriads, for the same range of country.

We have seen that the trappean ash, the volcanic ash of the period, was mingled with the gravels and sands now forming the conglomerates and sandstones in the Llandilo flag series, that it was accumulated in beds, interstratified with mud and sand, and that the remains of the crustaceans of the day are found in it.* This ash would point to subaerial volcanos, and probably therefore to land from which it may have been carried within a reasonable distance.

It may be desirable here briefly to notice two localities where the igneous and fused products of the time are also mingled with the sediments and detritus of the same period, one at Llanwrtyd, the other near Builth, leaving the igneous rocks of Pembrokeshire for future consideration. At the former place there has been considerable interstratification of mud or clay, gravels, sands, trappean ash, and fused trap rocks. To the south-west of the Well House, conglomerates

* Shells are also discovered in the same beds.

formed of pieces of previously consolidated slates and sandstones, with rounded pieces of veinstone quartz, that once filled cracks or dislocations in them, are mingled with the slates, and a succession of these beds will be seen between Pentwyn on the south-east to Mynydd-Trawsnant on the north-west. On Cefn-Cwm-Yrfon we meet with interstratified bands of greenstone and trappean ash, the latter sometimes so consolidated as at first sight to appear like the former. By tracing the ash beds to Cefn-Trebedd-Gwilim, we can see that the ashy matter gradually disappears in their range to the south-west, so that finally the ash is lost and common sands or gravels, as the case may have been, alone formed the continuation of the same beds in that direction.

We here appear to have evidence of ordinary detritus becoming mingled with volcanic products in such a manner as to show the direction whence the latter came. Tracing them, therefore, to the north-west, solid trappean rock presents itself, which has so altered the adjacent slates brought into contact with it, as to show that it has been forced among the sedimentary matter after, at least, its deposit. Though we do not possess any good evidence as to whether the beds were then consolidated to any extent or not, there is still enough to prove that igneous action took place somewhat at a point in this locality, and that fused rock in a melted state and ashes were ejected and much intermingled, subsequently to which the action was renewed in the same place, and the previous accumulations altered or metamorphosed when brought into contact with a heated mass. The manner in which the gravels are arranged point to shallow water for their accumulation, distributed as they are in lines amid the mud, clay, or silt, and perhaps at this point we may even have had a subaerial volcano, though of no great magnitude, from whence ash was ejected into the atmosphere, and distributed around amid the sands and sedimentary deposits then in progress.

At Builth there is a very interesting mixture of similar rocks, and some of the alterations effected by the intrusion of igneous matter in fusion are most instructive. Mr. Murchison has already pointed out that many of the igneous rocks of this district "were evolved from volcanic apertures during the submarine accumulation of the Lower Silurian rocks," and that other trappean rocks subsequently broke through the mixed masses altering the strata in contact with them.* He has also given a detailed section of the interstratified trappean and sedimentary beds in the range of the Carneddau.†

Judging from the quantity of ash, in some places mingled with the general mass of rocks, from the mode of its admixture with them, and from the conglomerates formed of rolled pieces (occasionally large) of

* Silurian System, vol. i. p. 330. † Ib. vol. p. 325.

the trappean rocks, sometimes immediately subjacent, as at Tan-y-Graig, we might infer that not only did many of these accumulations take place in shallow water, but also that there might have been subaerial vents whence ashes and lapilli were discharged. These ash and detrital accumulations were now and then thrown aside and pierced by masses of melted rocks, also frequently subaerial or ejected beneath moderate sea pressure, as would appear from their vesicular condition. The accompanying sections (Plate 3) will illustrate the general mode of occurrence of this accumulation.

It will be observed that masses of trap alter the sedimentary deposits with which they come in contact in some places, and were therefore produced subsequently to them, while pebbles and boulders have been formed of, and rest upon, similar masses in others, succeeded by sand, ashes, or black mud, as the case may be.

The organic remains entombed in the sedimentary deposits point to one geological epoch for the whole accumulation, so that we seem to have before us that association of igneous products, with the ordinary sedimentary and detrital accumulations of the period, which would have resulted from the local action of volcanic forces ejecting ashes into the air and molten matter either into the air or beneath slight pressure of water, the sea tenanted by the *Asaphus Buchii* and *Trinucleus fimbriatus*, in great numbers, and by *Graptolites*, often in multitudes.

Some of the changes of the sedimentary deposits effected by the heated molten rock in juxtaposition, have even amounted to a melting of such rocks and their consequent incorporation, in part, with those in igneous fusion at the time. Some of the intermixtures of the ashes and solid greenstones or porphyries are difficult to explain without this hypothesis, and at the north end of the Carneddau (near the range of the word upon the Ordnance maps), there can be little doubt that detrital rocks, chiefly composed of felspathic matter, have been so melted between two masses of greenstone, greenstone porphyry, and vesicular trap, as to form one body with them, their original bedded character appearing both on the north and the south, and the change from the one condition to the other being very gradual. Great care is required while studying this portion of country not to confound trappean ash so consolidated as closely to resemble greenstone or other trappean substances with true fused rocks, since organic remains are to be discovered in many beds which, at first sight, perfectly resemble those which have undergone fusion. Supposed thin-bedded trap, with well defined and even planes above and beneath, should be classed as such with much caution, for it may be merely a highly consolidated ash bed; and this care is more particularly needed in such a district as that under

consideration, where the juxtaposition of ash with masses of matter which without doubt have been in fusion is so frequent.

Some colourless argillaceous accumulations have become by metamorphic action large natural beds of biscuit china, the elementary substances being the same as a potter might employ for the purpose. To these beds Mr. Murchison has given the very appropriate name of *porcellanite*. Rocks of this class, though not of the finer varieties, are seen in the range of the Carneddau (and towards the locality where the complete fusion above mentioned takes place) to contain crystals of felspar, so as to constitute a sort of porphyritic slate. A kind of alteration showing that the conditions attending it were such as to permit a movement of particles so that some of the component elementary substances could adjust themselves in a definite manner, and complete the crystallization of the compound formed, while the remainder retained a coarse porcellanic character, the body of the rock keeping the lamination due to the original deposit of fine detrital matter from mechanical suspension in water.

To show the influence of the various conducting powers of the different rocks, as regards heat, it may be observed that though there are abundant examples of the alteration of the black slates from the influence of masses of hot trappean rocks in juxtaposition, the depth to which this may be observed is, usually, all other things being equal, much less in the case of these slates than in those where more colourless felspathic rocks are similarly situated, pointing to the inferior conducting powers of the carbon contained in the black slates as the probable cause of the difference.

It would be out of place here to enter further into the probable causes of the changes which have been already so well noticed by Mr. Murchison, such as the occurrence of iron pyrites, often in such abundance, replacing shells and graptolites, and spheroids of the same mineral, as it were displacing adjoining matter in the altered rocks. Indeed the metamorphisms observed require to be treated with reference to that subject generally, affording as they often do such excellent examples of the power of particles of matter, forming substances which have been gathered together by different means, to adjust themselves to the new influences to which they became exposed. Affinities are brought into force which were previously prevented from action, and changes are produced not only by the mere heat, too exclusively supposed to have effected the changes observed, but also by other powers, among which galvanic influence should receive its due attention.

At Malvern, also, volcanic action appears to have been experienced at this period, the main mass of the syenitic and granitic rocks of the Malvern Hills having probably been previously formed, so that the

intermixture and the intrusion of trappean rocks observed among the black slates, exposed on the southern part of that district, may have been among the last efforts of igneous action in this locality.

We would, therefore, appear to have evidence that during the period when the Llandilo flags and their equivalents in the Silurian system were accumulated over the area extending from Malvern to Pembrokeshire (for we must here so far notice the igneous products of that country as to observe that evidence exists there of local igneous action, apparently in part subaerial, at this geological period), volcanic points existed from whence molten matter and often ashes were ejected and were intermingled with the detrital accumulations of the period, and that black mud was a common sediment of the time, the colour of this mud due chiefly to carbon,* which we might infer was derived from vegetable matter. Of what kind this vegetable matter may have been there would appear no direct evidence, and though we might be disposed to infer that marine plants may have furnished a large part of it, when we regard the quantity of fine sediment of the time and its extent, we should look, in accordance with the mode in which such sedimentary matter is furnished in the present day, to land, its disintegration, and its removal by rivers and such running waters to the sea, as among the chief sources of the non-carbonaceous part of this black mud. Hence, and considering the conditions under which the remains of plants are likely to be preserved, it would probably be premature to look more than to plants generally, not altogether excluding animal matter, for the carbon required.

Be the origin of the black mud what it may, tranquillity was essential to its deposit and repose, until at least it had a fair amount of cohesion of parts, resembling clay. As volcanic action, seeming to mark subaerial conditions, has apparently supplied accumulations intimately mixed with this fine sediment, seas of no very great depth would appear to be required. It is only in comparatively sheltered localities, or in deep waters that fine mud accumulates in the present tidal seas, though it can come to rest and remain undisturbed in those which are tideless in less depths. In both, however, it is liable to be worked up by the action of the waves produced by winds. This leads us to regard the probable character of the latter and their power and direction at early geological times.

It is sufficient for the present purpose that the general action of the trade winds and other great movements of the atmosphere may be considered, disregarding modifications, as due to the heat of the equatorial portions of the globe, the cold of the poles, the distribution of land and

* Dr. Playfair ascertained, at the laboratory of the Museum of Economic Geology, that an average specimen of black slate, with graptolites, from near Haverfordwest, contained 5 per cent. of carbon.

water, and the varied exposure of the north and south hemispheres to the influence of the sun according to the seasons. Under the hypothesis that our planet has gradually cooled down from a state of igneous fusion to the present state, in which its surface is brought under the heating influence of the sun, an hypothesis which, if it be not the true one, is at least more fertile in explanation of a mass of geological phenomena than any other which we yet possess, a very different state of the atmosphere would exist in the early geological period under consideration. It has been supposed by M. Adolphe Brongniart that a heavy moist atmosphere, far more abounding with carbonic acid than at present, was that suited to the vegetation which flourished and was entombed at a subsequent epoch, that of the coal measures, and Professor Owen has extended this view of an atmosphere more loaded with carbonic acid than at present even to those geological times when great reptiles existed in such abundance.

The condition of things which has been supposed (the heat of the sun superseded or rendered non-effective by that derived from the interior of the earth) would be favourable to considerable stagnation of the air. There would be no apparent cause for such prevalent atmospheric movements as the westerly and south-westerly winds which now raise such waves and cause such heavy breakers to fall upon our Atlantic shores. Upon this hypothesis we might expect a more easy and general accumulation of mud in less depths than at present, though if the seas were tidal there would still be the movement on the bottom arising from the to-and-fro friction of the tidal wave where brought into such action.

The gravels and coarse sandstones intermingled with the Llandilo flag series do not often present the character of beaches raised by breakers, but rather of detritus propelled over prior accumulations of mud and clay by the action of running waters, such as rivers forcing gravel and sands seaward over a bottom previously raised to the proper height for such action by the prior accumulations. Certainly, however, in the Carneddau range near Builth, there are conglomerates more resembling those accumulated as beaches round a coast, and, in this case, one of a volcanic country, as for examples, behind Tan-y-Graig, and between Llanelwedd and Gelli Cadwgan. The rounded fragments of a variety of greenstones, greenstone porphyries, vesicular and other trap rocks are there mixed up with ash in a manner that has the aspect of a beach. In the second case noticed, and indeed in some other conglomerates, there are portions of the porcellanite and other altered rocks, showing the accumulation of mud, boulders, and gravels, after some, at least, of the metamorphic changes caused by igneous eruptions had been effected.

Though we might be inclined to assume much general tranquillity,

arising from the absence of many of those causes of prevalent winds which now exist, and to seek such tranquillity in less depths than at present, we can readily imagine many causes of a disturbed atmosphere sufficient to produce winds, and consequent breakers of power adequate to the rounding of rock fragments, and yet not those great waves over a large area acting so frequently in one direction which we now see. Many an arm of the sea and estuary will show the effect of the breakers, which sometimes there occur, from the short seas, as they are termed, that are raised in them by the wind, the effects of which only extend to small depths. On the shores of volcanos, moreover, we should expect that the rounding of fragments might be assisted by the breakers produced during earthquakes, which though transient and unfrequent, are still often very considerable, washing heavier bodies into the mass of a beach than would be mingled together under the action of the ordinary breakers.

Above the accumulations noticed, and which constitute the Llandilo flag series of Mr. Murchison, we find an arenaceous and gravel deposit, known as the Caradoc sandstone (No. 9 of the sections), beds of which are well seen at Malvern, May Hill, and Uske, and partially at Woolhope. Muddy matter was sometimes interstratified with the arenaceous, more particularly in the higher part, as at Malvern, May Hill, and Uske. As these sandstones and conglomerates do not occur at Builth, where the shales above them, known as the Wenlock shales, distinctly pass into the upper part of the Llandilo flag series, there having, in fact, been in that locality no interruption to the accumulation of mud or clay, while at a particular time it was so interrupted at the places above mentioned, it is interesting to consider, with a map before us, that the conditions under which these sands and gravels were accumulated were limited westward by a line passing from between Builth and Presteign southwards to the westward of Uske, where it will be observed by the sections that these accumulations are reduced to a few sandstone beds, mingled with shales, 110 feet thick, while at Malvern their thickness is 930 feet. From Builth westward there would appear no distinct beds referable to the Caradoc sandstone, and separable from the accumulations which have been formed in that direction.

The very interesting fact has been noticed by Professor Phillips* (first observed by his sister, Miss Phillips) of the conglomerate and breccia of the Caradoc sandstone series, where they rest upon the syenitic rock near Malvern, being composed of rounded portions and angular fragments of the subjacent rock, thus proving that the syenite was consolidated prior to the formation of the Caradoc sandstone deposits, and had not thrust them up, as had been supposed, into their present

* London, Edinburgh, and Dublin Philosophical Journal, October, 1842.

position. The manner in which the fossils are intermingled in this conglomerate and breccia, uninjured in cavities filled with mud, silt, or sand, seems to show that the pebbles or fragments of syenite were removed from the action of breakers, it may have been in sufficiently deep water at the base of a cliff, otherwise the corals and shells must have been crushed. The conditions would rather appear of the order noticed above (p. 13), where pebbles shoved into deep water became mingled with fragments which fell from the cliff above, there being sufficient cavities or interstices among the pebbles and fragments to permit animals to live amid them, the cavities being subsequently filled by mud, silt, or sand, upon a change of general conditions.

A general view of the geological map of the Malvern district would lead us to consider that the present separation of the main range of the syenitic and granitic rocks from the Caradoc sandstones, with the exception of a patch of ground in the vicinity of the locality above noticed, is due in a great measure to denuding action, which has worn away the connecting portions. We may regard the igneous eruptions at Malvern as having ceased with the black mud of the Llandilo flag period, and infer that sands and gravels accumulated round the old igneous region, covering up the black mud in more localities than the one where we now see them in contact with the main mass of the igneous rock.

In the ascending order we next arrive at a mass of mud or clay of great thickness and extent, the accumulation of which was accompanied by a deposit of much calcareous matter in the eastern part of the area under consideration. To the resulting rocks Mr. Murchison has assigned the name of Wenlock Shales. Including the limestone at the top of them, on the east, named Wenlock Limestone, and that at the bottom (the Woolhope) in the same direction, we have in the Malvern section a thickness of these rocks of 980 feet, at Woolhope, 1460 feet, and at May Hill, 1720 feet, showing a thickening of the deposit in that direction. The measurements of the sections give a thinning off from hence towards Uske, where we only find 630 feet for the same accumulations; but they are again thick near Builth, at which place the measurements give 1560 feet for their depth.

The manner in which the calcareous matter has been arranged during the deposit of these beds is deserving of attention, for while some of the limestones are little else than accumulations of organic remains, among which corals are prominent, other calcareous portions seem to have been produced from carbonate of lime thrown down from chemical solution in water, sometimes in bands, at others mingled with the mud or clay.*

* The dolomitic Wenlock limestone, 5 *a* of the May Hill section (p. 22), is deserving of notice, inasmuch as the per-centage of carbonate of magnesia in it is somewhat consider-

In the Malvern section, the lower or Woolhope limestone is formed of only a few thin bands of limestone, mingled with shales and sandstones, the whole about 80 feet thick. At Woolhope the calcareous matter has become more abundant, sufficiently so to be worked for economic purposes, thin shales being only interstratified with it; and its thickness is 180 feet. The same accumulation is 240 feet deep at May Hill, and of about the same thickness at Uske, comprising all under Nos. 7 and 8 of that section. At Builth there is no trace of these limestone beds.

The upper or Wenlock limestone is about 240 feet thick, including associated shales, at Malvern, 150 feet at Woolhope, 340 at May Hill, 100 feet at Uske, and merely to be traced by about 10 feet of calcareous nodules and interrupted beds at Builth, after which, westward, it is not seen. We may so far remark upon the Silurian area beyond that under consideration as to observe, though the Wenlock limestone disappears westward of Builth, that comprising the country between the latter and the Wenlock district itself, the Dudley and Walsall country, with the Tortworth districts in Gloucestershire, Uske, May Hill, Woolhope, Malvern, and the Abberley range, we have evidence that this accumulation of calcareous matter was effected under nearly the same general conditions over an area of about 2600 square miles. We have to assume that beneath the mass of Old Red Sandstone and other covering rocks, this limestone, with its associated shales, has been continuous, and fortunately the protrusions through them enable us to infer without difficulty that this has been the case.

A large part of this limestone seems due to the accumulation of organic remains, corals being numerous. When well weathered the rock is often seen to be a mass of such remains, accumulated in a manner in which we may consider them to be arranged at the bottom of many seas. Judging from the mud or clay bands with which they are interstratified, and the general character of the Wenlock shales as a whole, we should expect that there was considerable tranquillity over the area upon which the mass was accumulated; indeed, the sharp, beautifully preserved

able, as compared with the limestones of this date generally within the district under notice. Mr. Trenham Reeks, of the Museum of Economic Geology, obtained the following results from an analysis of it:—

Carbonate of lime	60·8
Carbonate of magnesia	28·3
Protocarbonate of manganese	1·4
Protocarbonate of iron	6·7
Silica	4
Alumina	0·3
Water	0·8
Traces of carbonaceous matter, and loss	0·3
	100·0

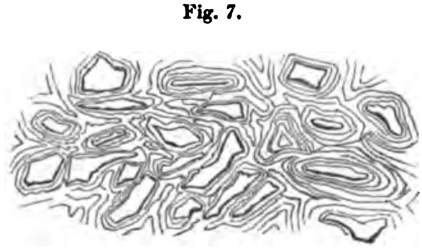
forms of the various trilobites, molluscs, and corals, show that they have suffered little or no attrition.

Besides these sheets, as it were, of calcareous matter, the greater part of which has been accumulated where we now find it by means of the animal life of the period, many a chemical decomposition and recomposition of the harder parts of some of the animals, in the manner previously noticed (p. 18), forming limestone beds, wholly or in part, the numerous nodules, like cannon-balls, distributed through many parts of the Wenlock shales in certain localities, sometimes plane above plane, would point to a separation of the calcareous matter from the mass of the mud deposit after its first accumulation.

Some ranges of apparent nodules are but the sections of planes covered by corals, and care should be taken not to confound them with those true nodules which are usually formed of an argillaceous limestone. Though these may contain organic remains, they are very frequently without them. At Builth, where there is only a trace of the Wenlock limestone and the Woolhope limestone has altogether disappeared, these nodules are very numerous. As to a certain extent marking their relative date of formation, it may be observed that Orthocera or Criseis when enveloped in them are not flattened or crushed as always happens when they are found in the adjacent shales, so that these fragile bodies were probably not flattened by the accumulating weight of the mud or clay before the nodules adjacent to them were produced, and we may consider the beds of mud or clay, when the nodules were formed, as having been in a soft state, and that the nodules may have been produced during the formation of the general mass, series above series, while the necessary conditions obtained.

From Builth, where the limestone nodules are so abundant, the calcareous matter gradually disappears in the range of the Wenlock shales to the south-west. In a quarry near Maes-cefn-y-ffordd, about two miles north-east from Llangammarch, we found the following interesting example (Fig. 7) of the loss of calcareous matter, probably from existing atmospheric influences, much carbonate of lime having

Fig. 7.



been gradually removed by water containing carbonic acid, and a consequent new arrangement of some parts with the remaining portions of limestone having given the false character of a breccia to the mass, so that fragments of argillaceous limestone have the deceptive appearance of being dispersed through the shale.

As during the lapse of time many a modification of this order may have been effected, and dispersed and original calcareous matter may have been chemically removed, we may conclude that often where such calcareous matter cannot now be found, in ranges of beds similar to those under consideration, it may still have originally existed, very minutely disseminated beyond the distances where it can be at present traced.

As the calcareous matter gradually disappears in the range of these beds to the south-west, arenaceous matter becomes as gradually introduced; so that, finally, near Llangadock and Llandilo, thin sandstone beds are common,* and the whole more and more partakes of an arenaceous character before this portion of the Silurian series becomes overlapped by the old red sandstone towards Caermarthen. Observing this tendency of the Wenlock shales to lose the character from which they derive and deserve their name on the eastward, we should expect that the sandy character would continue to increase westward beneath the overlap; and this would appear to be the case, for at the exposure of the Silurian rocks by undulations and denudation in southern Pembrokeshire, and at the section in Marloes Bay, the beds which may in any way be considered as equivalent to the whole or part of the Wenlock shales of the east, are chiefly sandstones. Consequently, we should expect much modification in the mode of occurrence and kind of the organic remains discovered, an expectation which is apparently realized in South Pembrokeshire, where similar conditions having continued to prevail beyond the time they were in force over the eastern part of the area, certain animals may have continued to exist on the west, which were cut off at an earlier geological date on the east. While the sea bottom was sandy on the west, it was formed of mud or clay on the east,—many animals abounding on the east and leaving their hard parts to mark both their existence and abundance, are scarcely found on the west; among these are numerous lines of corals, occasionally forming accumulations amounting to coral reefs, the fruitful source of many limestones.

Similar differences between the east and west portions of the area continue above the geological horizon of the Wenlock limestones to

* In the neighbourhood of Builth, a band of argillo-arenaceous rock, about 250 feet thick (6*b*, Builth section, p. 23), occurs in the midst of the Wenlock shales of that locality. It disappears to the south-west, merging into the mass of arenaceous rocks in that direction.

the beds named Ludlow Rocks, by Mr. Murchison. The lower portions of these beds, or Lower Ludlow Rocks at Malvern, are formed of shales, with bands of calcareous nodules towards their base, 700 feet thick. At Woolhope they present the same characters, and are of about the same thickness. At May Hill, still preserving the same characters, they are only 140 feet deep, and do not differ at Uske, except in an increase of thickness to 190 feet. At all these places they offer the same general aspect as that noticed by Mr. Murchison on the south-west of Salop and the adjacent parts of Herefordshire, where, he observes, "they constitute a great argillaceous mass, strictly entitled to the provincial name of Mudstone."*

This accumulation of mud or clay may be considered, on the east, as a part or continuation of that which preceded it, presenting the same general physical characters. It is surmounted by the limestone known as that of Aymestry, from the village of the same name.† In the Malvern section this limestone occurs as a subcalcareous rock in nodular beds, 40 feet thick. At Woolhope it is represented in the same manner and of the same thickness, with perhaps the addition beneath of 40 feet of shales and thin beds of limestones. The May Hill sections do not present us with any marked beds referable to this rock. At Uske we may probably consider it represented by some thinly laminated calcareous beds, about 30 feet thick; at least, they would appear to occur in a nearly similar part of the section.

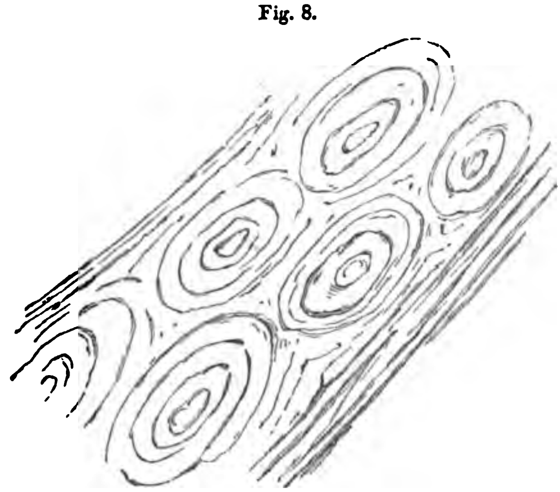
Quitting these localities, we find at Mynydd Aberedw, near Builth, a thin band, composed of little else than the remains of *Pentamerus Knightii*, the shell which occurs in such profusion at Aymestry. Assuming this band to represent the Aymestry limestone, the Lower Ludlow Rocks near Builth have become greatly modified from their equivalents at Malvern, Woolhope, May Hill, and Uske. They constitute the base of a considerable thickness of arenaceous rocks, interposed, near Builth, between the Old Red Sandstone and the Wenlock shales, and are the only representatives, in that locality, of the Lower Ludlow Rock. These arenaceous beds not only present oblique planes of false bedding, pointing to the propelling action of water over the bottom, driving the grains of sand onwards by friction, but also large spheroidal masses, apparently concretions formed after the deposit of the beds, since the forms of these concretions lead us to conclude that a new adjustment of parts took place round points, so that concentric spheroids were produced.

* Silurian System, vol. i. p. 204.

† It was in this vicinity that the Rev. T. T. Lewis worked so sedulously at the fossils of its rocks. Mr. Murchison has more especially called attention to his labours upon those of the Aymestry limestone, Silurian System, vol. i. p. 201.

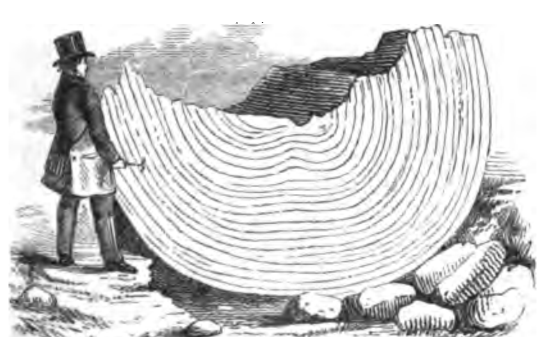
The following section (Fig. 8), seen at Cwm-graig-ddu, between Builth and Llangammarch, will exhibit the manner in which beds marked by these concretions are interstratified with others, where the same re-arrangement of parts has not been effected:—

Fig. 8.



The concretions are often several feet in diameter. The annexed sketch, taken at Erw Gilfach, near Builth, shows one of large size, which though not among these equivalents of the Lower Ludlow Rocks, and found lower down in the series amid the Wenlock shales of the same neighbourhood, where similar conditions produced accumulations of the same kind at an earlier period, still represents the general character of the spheroidal concretions of large size in the Lower Ludlow Rocks of the vicinity.*

Fig. 9.

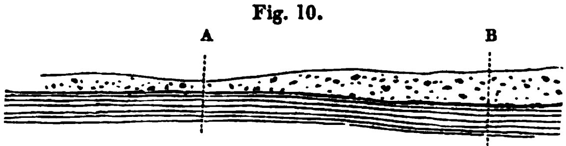


* See Note, p. 41.

It will be seen that while mud, mingled with some calcareous matter, has formed the accumulations of this geological date at Malvern, and as noticed by Mr. Murchison, those of Ludlow and Wenlock, at Builth there has been a mixture of sand, also with calcareous matter sufficient to produce marked limestone beds,—another instance of the various Silurian accumulations above the Llandilo flags becoming sandy in their extension towards that part of the area now occupied by southern Pembrokeshire. Towards Llangadock the Lower Ludlow Rocks merge into the mass of arenaceous beds exhibited in the beautiful natural section afforded by the Sawdde.

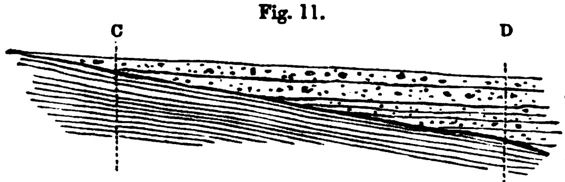
The thickness of the beds above the Aymestry limestone varies most materially; at least as far as the sections showing the contact with the old red sandstone above them permit this thickness to be seen; for it should always be borne in mind, that when we suppose a complete section before us, we also suppose no overlap of any of the beds. When very material differences in the thickness of accumulations, considered equivalent, are found, we have to view such differences, either as resulting from the variable amount of contemporaneous accumulations over a given area, as shown in the section, Fig. 10, where the original thickness

Fig. 10.



of *a* above *b*, has been twice as much at B as at A, or from the beds of *a*, fig. 11, having gradually overlapped, so that only the last, or higher

Fig. 11.



beds, of *a* cover at C, overspreading many which were previously deposited at D.

This is most frequently a problem of much difficulty to solve, but when equivalents of the various parts, or groups of beds, can be determined, it is one of great interest. It is not improbable that in the area before us, the old red sandstone has produced much apparent difference in the thickness of the Silurian rocks above the Aymestry limestone, in the upper Ludlow rocks, as they are termed, by overlap, since, as above noticed, we have distinct evidence of its overlapping character, from the

vicinity of Llandilo westward. At the same time, from their character, we might anticipate much variation in the depth of these rocks at this period, contemporaneous accumulations being thicker in one place than at another.

Gray shaly sandstones, surmounted by white, yellow, and brown sandstones, with shale partings, the whole 300 feet thick, constitutes this upper member of the Silurian series at Malvern. Rocks of precisely the same general characters, showing a thinner accumulation of the lower gray shaly sandstones, as also a somewhat less thickness of the white, yellow, and brown sandstones above them, are found at Woolhope; the total accumulation being diminished by more than a third, in the distance of about five miles. The upper Ludlow rocks of May Hill present much the same thickness and character on its northern part as at Woolhope, though it should be obsreved, that there are many modifications of the upper arenaceous beds, in their course from Soller's Hope and Much Marcle, to Gorstley Common, in the prolongation of the Woolhope protrusion, and that on the west of Taynton House, on the eastern side of May Hill, red beds, perhaps so coloured from a former covering of some members of the New Red Sandstone series,* are observed with the fossils of the Ludlow rocks.

At Uske, the general characters of the Upper Ludlow Rocks do not much differ from those above mentioned; but when we arrive at the Builth sections, we observe an enormous increase in the thickness of the upper portion of the Silurian series. Instead of the 300 feet of the Malvern section, we find a depth of 3,188 feet,† without including those beds formerly classed with the Old Red Sandstone, and named the tilestones, from being extensively worked and employed for the roofing of houses. The finely laminated and micaceous beds of the tilestones, replete with organic remains, do not reach from the westward so far as Builth, but terminate not far north-westward from Cwm-craig-ddu, merging partly into the more common form of argillo-arenaceous beds of the upper Ludlow rocks of that vicinity, and partly becoming broken up by red marls. This considerable thickness presents a very common general aspect, both as regards mineral character and organic remains. The beds so resemble each other, that there is little difference in their fine-grained and thin-bedded structure, occasionally calcareous, for their whole depth, and the *Leptæna lata*, *Terebratula navicula*, and some

* The staining of subjacent rocks by the peroxide of iron passing down from supercumbent beds, charged with that substance, is a well known fact in many localities, and is often very useful in showing a covering of such works to have been effected prior to denudations which have removed such red beds, and not unfrequently also a large mass of the subjacent rocks.

† This measurement was made with great care along the fine natural section exposed at Cwm-craig-ddu,between Builth and Llangammarch. No trace of a fault.

other shells seem common throughout, as we might expect from the continuance of the same conditions under which the general mass was probably accumulated. The whole seems as if it were deposited from mechanical suspension, the water occasionally holding bicarbonate of lime in solution,* layer succeeding layer; the creatures living on and in the silt being gradually entombed; their different states of growth, as shown in the layers of rock, marking a long lapse of time for the general accumulation.

In the vicinity of Builth it becomes no easy task to determine a boundary line between this gray and thin bedded silt deposit, and the Old Red Sandstone. After the disappearance of the tilestone bands coming from the west (which, if they do not always form a very defined natural line of separation, constitute at all events a very convenient one in the present state of our knowledge), the determination of the supposed line becomes indistinct for a long distance towards Presteign. At Craig-y-pwll du, near Erwood, where a very fine natural section is afforded, gray sandstone beds, mingled with shales, and here and there a reddish marl, surmount the finely laminated rocks above mentioned, and there are occasional beds of sandstone containing organic remains (*Lingulæ*), mingled with the red marls much higher up in the series.

To the south west, the upper part of the tilestone beds may be taken as a convenient boundary of the Silurian Rocks, against the Old Red Sandstone, until they disappear in the overlap between Llandilo and Caermarthen; yet by taking this line of deposits, we are compelled to include in the Silurian series 600 feet of red sandstones and marls, in the section of the Sawdde, which in no respect differ mineralogically from the general mass of the Old Red Sandstone of that locality above about 390 feet of the beds referable to the tilestone accumulations. In fact, by adopting this course, we have to include a flattened mass of red marl and sandstone; showing that the causes productive of the great accumulation of red sandstones and marls, above the tilestones, commenced in this part of the area, before they did so to the north eastward and eastward. The whole appears to prove, that the change from the

* Bearing in mind the dissemination of calcareous matter which may be effected from its solution in one place by percolating waters, containing carbonic acid, and its deposit in another, under favourable conditions, it may sometimes happen that the removal of the carbonate of lime of shells, leaving only casts, as they are termed (a very common fact among the rocks under notice), may produce its aggregation in numerous cracks and fissures, and even in lines of bedding, thus giving a calcareous aspect to adjacent slates and arenaceous rocks. Such a rearrangement of calcareous matter may still be accompanied by a general loss of that substance through springs, such new arrangement being only partial, much carbonate of lime still passing off as a bicarbonate in solution, and the arrested calcareous matter, after a time, being again liable to removal when that first and most easily borne off in solution has been transferred to other situations by the waters discharged as springs.

conditions productive of the Silurian rocks, to those which formed the old red sandstone, was not sudden over the area under consideration, but that while the red accumulations were effected 600 feet thick in the direction of Llangadock, gray finely laminated silt beds continued to be thrown down near Builth; for the continuation of the tilestone bands can be traced with great precision the whole distance, clearly showing those beds which were deposited before and after them.

Whether the tilestones became merely buried beneath overspreading beds of the Old Red Sandstone, at the overlap between Llandilo and Caermarthen, or terminate there, as they do towards Builth, is not apparent; but we can readily consider them as sandy micaceous accumulations, replete with multitudes of molluscs which the conditions suited, these accumulations distributed locally in patches several miles in length and breadth, like the sandbanks of our own time, and therefore presented to our view, not in continuous bands for great distances, but here and there, where movements of the rocks or denudations bring them in the sections before us, a manner in which we should regard most accumulations of a similar kind.

Collectively, the mass of matter noticed under the head of Silurian Rocks is very large, viewing only the limited area under consideration. Extending that area for the moment, and no further than the boundaries of the Silurian Rocks of Wales and the adjoining English counties, many cubic miles of mineral matter have to be worn away from pre-existing rocks and to be transported to the localities where we now find it deposited. Here and there this mass of detritus is mingled with other matter which has been melted and introduced among it, but yet not in sufficient quantity to form any large amount of the general deposit, except in minor localities. Granitic rocks could readily furnish the quartz, mica, and clays, of which the great proportion of this detrital accumulation is composed, and assuming that granitic rocks of the ordinary kinds with, perhaps, gneiss, mica slate, and other rocks of that class did furnish the requisite materials (the decomposition of felspars having greatly aided the production of clays and that solution of silica which subsequently has so materially entered into the substances cementing the sand, silt, and mud into firm rocks), we may be led to inquire if the state of the atmosphere at this early geological period may not have been such as very materially to promote the decomposition of rocks into which felspar entered as a component part. The hypothesis that at and anterior to the formation of the coal measures, carbonic acid was more abundant in the atmosphere than at present (an hypothesis which has lately been received with much favour), would be found useful in accounting for a more speedy and effective decomposition, by atmospheric influences, of a given mass of similar granitic rocks at that

time than at present, inasmuch as a damp atmosphere, well charged with carbonic acid, would be favourable for the decomposition and disintegration of many granitic rocks, and, in consequence, would very materially promote conditions for the solution of silica and the ready supply of detritus to running waters, inland, as well as for the wearing away of coasts by the breakers.

As many cubic miles of detrital matter require an equal amount of pre-existing rocks to be destroyed, the one mass supplies the place of the other, and, therefore, we can only expect to find the remains of such pre-existing rocks left, as may have resisted the destructive action, not only of that period, but also of all those which have intervened between it and the present time. Moreover we have to consider, in accordance with the mode in which detrital matter is now removed, to be deposited by means of water, that the mass of detritus under consideration was carried away from rocks above water at the time of their disintegration or abrasion, so that in the course of geological time these pre-existing rocks may have been either worn away or buried beneath gravels, sands, and mud, in the same manner as we see many accumulations which have been effected in the seas of later geological periods, covering beds which were worn down, and even sometimes furnished the materials of which the higher rocks are composed.

To return to the minor area under consideration, we have evidence that during the deposit of the Silurian Rocks in it beds were consolidated, abraded, and the materials re-used, for we find even in the conglomerates of the Llandilo flags, fragments of slates, and sandstones, altogether resembling portions of subjacent rocks, mingled with pieces of vein quartz, once probably filling up the cracks of the beds abraded.*

At Malvern we have evidence of the wearing away of the igneous rocks of the Malvern Hills to produce a part of the substance of the Caradoc Sandstone of that locality, as noticed by Professor Phillips,† neither the igneous nor detrital rocks then occurring as now relatively to the horizon, but nearly at right angles to their present position. This shows that the igneous rocks were probably out of water at the time. Similar pebbles are observed in the conglomerates of May Hill, but we cannot thence infer that they were derived from the Malvern range, for there may have been similar rocks in the intermediate distance, now

* The vein quartz in many conglomerates is deserving of attention as showing how the silica, often derived from the decomposition of pre-existing rocks, finds its way in solution into cracks and fissures, in more newly consolidated beds, there taking the solid form, and afterwards when the including rocks are decomposed, or broken up and removed, again forming a component portion of still newer rocks. Even as pebbles there is reason to suppose that quartz is used over again, the destruction of one conglomerate aiding the formation of another.

† London, Edinburgh, and Dublin Philosophical Journal, October, 1842.

destroyed or covered up; the fact is, however, useful as showing that part, at least, of the Caradoc sandstones there accumulated may have been derived from land at no great distance. As another instance of dry land,* above the early accumulations of the period, whence materials were furnished for these deposits, we may probably look to the range of the Carneddau, north of Builth, where we have not only conglomerates formed of subjacent igneous rocks, but trappean ash, ejected probably from the same locality, as also vesicular igneous rocks marking but light pressure upon them when in fusion. Among these conglomerates we have pieces of the altered rocks of the immediate neighbourhood, both the removal and rounding of which would imply somewhat shallow water. Indeed, this portion of country would appear to have been at least partially out of water during the period of the Llandilo flags, subsequent deposits having accumulated around and upon it.

How far any of the conglomerates of the Llandilo flag series, extending from Dol Van, between Builth and Rhayader, to and beyond Caermarthen, may have been beaches, it is difficult to say. Some, by their mode of arrangement and mixture with the other beds, certainly resemble sections which we may readily consider beaches at the mouths of rivers often to present, if cut down through the sands and mud over which they have accumulated, the beaches subsequently submerged, and mud or silt deposited over them.

After the Llandilo flag series, during the formation of which the volcanos of the time seem to have ejected ashes, the deposits of the eastern part of the area under consideration were far more muddy than those of the western, the bank named the Caradoc sandstone excepted, the edges of which did not appear to extend westward beyond the line previously noticed (p. 37). This different character reaches vertically upwards through a considerable thickness of accumulations, pointing to a somewhat constant cause for the difference. On the supposition of a drift of the whole from a given direction we might look for the land, worn away and abraded to furnish the necessary detritus, as having existed to the westward; at the same time, if there were an extended coast, and one river or set of rivers brought down mud into a comparatively tranquil situation, and another river or set of rivers silt and sands, we might have the like effect from the gradual intermingling of the resulting deposits by tidal action, one which if the main ocean washed

* While thus endeavouring to form opinions of the ancient condition of such portions of country, we must carefully take into consideration the disturbances and movements to which the various accumulations have been subsequently subjected, so that deposits formed horizontally may be now presented to our view vertically, beaches with the rest, even the remaining portions of the land of the time bent up and contorted with the general mass.

the shores of the land whence the detritus was derived, we should expect to influence its accumulation in proportion to the configuration of the coast and the proximity of the deposits to the surface of the sea.

Calcareous matter seems also to have been more abundant among the upper Silurian rocks on the eastward than on the westward, mingling with the mud, and affording an efficient supply of carbonate of lime to the corals and molluscs which flourished in that direction. On the westward the upper beds of the Silurian series are not well seen, uncertainty arising from the overlap of the Old Red Sandstone in that direction, but as far as can be inferred, arenaceous conditions, life frequently abundant, finally obtained over the whole area at the close of the Silurian deposits, for the proper appreciation and first valuable descriptions of which we are indebted to the labours of Mr. Murchison.

Old Red Sandstone and Devonian Rocks.

We now arrive, at least over a large part of the portion of England and Wales under consideration, at a very marked change in the character of the deposits; not so suddenly indeed as has sometimes been supposed, for, as above stated (p. 46), the clear boundary upwards of the Silurian deposits is not so easily defined, a considerable thickness of red sandstones and marls occurring beneath the fossiliferous tilestones near Llangadock, and the tilestones themselves being apparently lost amid ordinary Upper Ludlow rocks, on the one hand, and red marls, on the other, towards Builth and Presteign, but still, regarding the masses, a most marked change. A large amount of beds, loaded with peroxide of iron, and affording, comparatively, few animal remains. and these chiefly in the lower portion, succeeds to the mud, sand, gravel, and limestone, often teeming with the organic remains previously noticed. Some great change of physical conditions, and one lasting during a longperiod, locally (for we have to reckon the depth of the Old Red Sandstone by thousands of feet), must have occurred to produce this difference.

Should accumulations of the kind observed in those of the Old Red Sandstone be now effected, they are concealed from our observation, if, at least, we are to consider that the iron in them was chiefly in a state of peroxide at the time of their deposit. Here and there, indeed, in red marl and shale countries, the rivers, during floods, are strongly coloured by the red matter in mechanical suspension, which when discharged into the sea is there deposited, so that red beds are so far accumulating. The peroxide of iron is washed from the sands derived from red sandstones, and this also is carried to sea to be deposited, so that the destruction of a red district of this kind furnishes the materials for more modern red deposits. By the action of the rivers and brooks, the peroxide of iron is usually removed from the grains of sand, which it had

previously enveloped, and the sand is carried forward without the red stain, while the fine peroxide and the mud are kept mechanically suspended, to be thrown down in some more distant and new situation.

When by itself, the peroxide of iron mechanically suspended in rivers is found to be very fatal to the animals previously living in them. It is well known in mining countries, where the peroxide of iron from the washings of the ores is borne down by the rivers, that the fish in them are destroyed, and should there be no deposit to prevent the peroxide reaching the sea, the marine creatures fly from it. We have made experiments to ascertain the influence of peroxide of iron upon marine and fresh-water life, and, as might be expected, the presence of this substance was found to be highly injurious to it, so that the animals quitted the peroxide of iron as speedily as conditions would permit. That, therefore, we should not discover many animal remains in these red deposits, such as those of corals and molluscs, is to be expected.

In the country of which Herefordshire forms the chief portion, extending to Shropshire in one direction, to Monmouthshire and Glamorganshire in another, and into Brecknockshire, Caermarthenshire, and Pembrokeshire in a third, we have an unbroken exposed surface of about 2100 square miles of old red sandstone, the whole, making due allowance for vertical differences between the upper and lower beds, of the same general character. Taking the average thickness of the mass, as it appears from measuring the beds vertically to their outcrop, we should have more than 1500 cubic miles of, chiefly, red-coloured detrital matter, for such it appears, with the exception of a slight amount of the limestones termed *cornstones*. We have hence in this area alone a large amount of detritus accumulated under conditions very different, as regards the admixture of ferruginous matter, from those which preceded it during the Silurian epoch. It is difficult to obtain a clear view, in the present state of our knowledge, of the causes which produced such a mixture of peroxide of iron with the accumulations formed during the lapse of time apparently required for the deposit of this amount of old red sandstone.

After a few sandstone beds, with *Lingulæ*, and perhaps some other shells, the last struggles, as it were, of the molluscs of the time to keep their ground in the waters covering this area, there would appear to be few other traces of animal life than the remains of fishes, and these chiefly in the cornstones, or limestones, associated with the red or variegated marls and sandstones.* Fishes could readily swim freely without injury in the waters from which the peroxide of iron was thrown down, so long as they did not disturb that substance at the bottom, while at

* Detailed accounts of the fishes found in the cornstones, are given by Mr. Murchison in his Silurian System, vol. ii.

the same time molluscs would be incapable of crawling upon or living in the mud or sand intermingled with the peroxide, as we have found by experiments; so that at any intervals when the waters might be relieved, by deposit, from their load of mechanically suspended peroxide of iron, the fish could readily enter the area exposed to this kind of red accumulation.

The remains of the fish being rarely discovered, except in the cornstones, there would appear some connexion between their entrance into the waters of the area and the conditions fitted for the deposit of the limestone. We may consider the streams of water bearing the calcareous matter to have been comparatively clear, and to have commonly remained so while the limestone was forming, at least, when the cornstones are not much intermingled with the red marls, as they must have been where we now find them thin and nodular, the calcareous matter fading by degrees into the marls.

Though the cornstones are mere flat patches of calcareous matter, of irregular forms, varying in length from a few hundred yards to two or three miles in the sections afforded, and commonly but a few feet in thickness, even when well developed, mere calcareous patches of varied form, scattered among the marls and sometimes the sandstones, collectively they are of geological importance as showing that bicarbonate of lime (for they all appear as deposited from chemical solution) was borne into the waters, covering the district under notice, with the finer detritus, and hence that, as regards the necessity for that substance, animals could readily have obtained carbonate of lime for their harder parts, if the other conditions for their existence had been favourable. We thus infer that the corals and molluscs were driven away from this area by the condition of the bottom and the frequent presence of peroxide of iron mechanically suspended in the waters, fish finding their way into the latter from adjoining clear seas and differently conditioned bottoms, where marine plants and animals could flourish.

The general character of the cornstones, their common position in the series of beds, their greater abundance eastward than westward, and the remains of the fishes found in them, have been described by Mr. Murchison.* They partake of the blue, green, and red colours, seen sometimes interstratified with each other in the sandstone and marl beds; colours of geological value, as showing the iron in different states of oxidation. The red colour is well known to be discharged where vegetable matter, under certain conditions, has become inter-

* Silurian System, vol. ii. The presence of the cornstones is commonly marked by quarries, when of fair thickness and purity of composition, being valued either for lime, when distant from better supplies, or for road materials, often scarce in the marl districts in which they are chiefly found.

mixed with the red marl or sandstone; and Captain James, R.E., has pointed out the probability, that the clefts and joints of the Old Red Sandstone, near Ross, Herefordshire,* have been turned from their original red colour, to the green and blue seen on their sides, by the percolation of water from the surface, charged with the needful substance to produce the change.

Though many of the green and blue bands among the marls are found to be calcareous, and half-developed cornstones, the carbonate of lime not being in sufficient quantity to form a limestone, there are other bands of the same colours in which this substance is not detected, and for which other causes of the difference of colour have to be sought. With the knowledge that under the conditions where vegetable acids are forming in contact with peroxide of iron, the latter is robbed of part of its oxygen, and converted into a protoxide, it is interesting to consider if the colours of these bands (often very marked and continuing over the same planes amid the red rocks for considerable areas, showing the operation of some common and widely spread contemporaneous cause over them) may not be due to a change produced upon the peroxide of iron by vegetable matter, the latter having entirely, or in a great measure disappeared, leaving little or no carbonaceous substance to mark its former presence, nearly the whole having been converted partly into acids, and partly into different gases.

Throughout the deposit of the Silurian rocks, and above the black shales (formerly black mud), wherein carbon is found (p. 35), we cannot suppose the animals, whose remains are often so abundantly entombed in the mud, silt and sand of the time, to have existed without marine vegetation, though we commonly find no trace of it, the vegetation with the soft parts of the animals having been decomposed and removed; and hence there is no great difficulty in supposing soft vegetable matter to have been carried by drift, or to have grown upon the sea bottoms, during the formation of the red marls and sandstones of this period; vegetable matter which, by decomposition in contact with peroxide of iron, could convert it into protoxide, the latter afterwards preserved under conditions unfavourable to its reconversion into a peroxide.

That gaseous matter, arising from some cause, found its way through some of the red mud, producing tubular cavities, would appear probable, reminding us of those formed in the mud at the bottom of many stagnant pools by the passage of light carburetted hydrogen, or marsh gas, upwards; for these tubular cavities, perpendicular to the planes of the marl beds, are to be seen in several localities, for the most part filled

* London, Dublin and Edinburgh Philosophical Magazine, 1843.

with carbonate of lime, the introduction of which has preserved their forms, and rendered their situation apparent. The following is a section of several of these beds on the north side of Freshwater East, Pembrokeshire :—

Junction of Silurian Rocks with the Old Red Sandstone, Northern side of Freshwater East, near Pembroke.

	Ft.	In.
1. Series of red marls, with tubular cavities vertical to the beds and filled with impure limestone of the same character as the cornstones of the Old Red Sandstone of Herefordshire	40	0
2. Red marls, with calcareous tubular portions, upper portion cornstone	17	0
3. Red marls and sandstones	7	0
4. Red marls, with vertical calcareous strings	5	0
5. Alternations of red marls and sandstones	6	0
6. Red marls, with calcareous vertical strings	2	0
7. Red marls	7	0
8. Greenish blue marls, some sandstone	16	0
9. Greenish blue marls, with vertical calcareous strings	3	0
10. Red marls, with calcareous vertical strings	14	0
11. Olive green shales	3	0
12. Olive green gray sandstone	2	6
13. Ditto ditto shales	1	6
14. Greenish gray sandstone, micaceous	3	0
15. Ditto ditto sandstone	1	0
16. Greenish gray micaceous shales	1	0
17. Greenish gray sandstone	3	0
18. Ditto ditto sandstone and arenaceous shales	1	6
19. Greenish gray sandstone	1	0
20. Greenish brown and fine-grained arenaceous shales, some yellowish green, with thin bands of gray sandstone, *fossiliferous*	20	0
21. Hard brownish green sandstones	1	10
22. Greenish brown sandstone and arenaceous shales	4	0

(Beds vertical or highly inclined.)

The section given certainly does not show the supposed tubular cavities above blue or greenish beds, except in No. 10, and therefore, though such instances may be adduced, gaseous emanations may have passed through the red mud from other causes than the decomposition of vegetable matter beneath, insufficient or not of a kind to form a protoxide from a peroxide of iron. Be this as it may, the apparent tubes are deserving of attention, the more especially as they do not remind us of any perforations by marine animals, for whose existence, indeed, the quantity of peroxide of iron in the adjacent red mud would appear to have been unfavourable.

The following analyses by Mr. Trenham Reeks,* of red and gray marls from the same locality, Hobbs Point, Milford Haven, Pembrokeshire, will illustrate the difference of the state of the iron in them, and

* At the laboratory of the Museum of Economic Geology.

the carbonaceous matter in the gray marl is interesting viewed in connexion with the supposition that the change of colour may have been produced by the presence of decomposing vegetable matter.* It will be observed that while in the red marl the iron is in the state of a peroxide, in the gray marl it exists both as a protoxide and a peroxide.

	Red Marl.	Gray Marl.
Silica	70·2	66·5
Alumina	19·2	22·9
Peroxide of iron	6·0	3·2
Protoxide of iron	..	1·7
Carbonate of lime	0·4	0·3
Chloride of sodium	0·1	..
Carbonaceous matter	..	1·3
Water	4·0	4·0
Loss	0·1	0·1
	100·0	100·0

· Traces of sulphate of lime in the gray marl.

Though the minor characters of the Old Red Sandstone accumulations change materially in some districts, lenticular masses of sandstone and marl being intermingled in endless variety, showing variable velocities of the transporting waters, the following section will afford a fair view of the mode of occurrence of the rocks in Herefordshire, where they exhibit, apparently, their most complete development.

Section of the lower portion of the Carboniferous Limestone, of the Old Red Sandstone, and of the upper part of the Silurian Rocks between Howl Hill, Dean Forest, to Welsh Court, Much Marcle, Herefordshire.

Lower Part of the Carboniferous Limestone, Howl Hill.

	Ft.	In.
1. Limestone (containing *Leptæna*)	4	0
2. Blue marl or shale	1	6
3. Limestone (a marked bed)	0	8
4. Blue marl, with thin beds of limestone	4	4
5. Limestone	1	0
6. Marl, with thin seams of limestone	1	0
7. Limestone	1	4
8. Blue marl, with thin seams of limestone	1	8
9. Limestone	0	4
10. Blue marl	0	4

* In a section measured with great care, after the above was written, of the old red sandstone, on the north of the carboniferous limestone of the Hook Point, county of Wexford, Ireland, in company with Captain James, R.E., Director of the Geological Survey of Ireland, we found repeated examples of the gray or bluish marls and sandstones containing the remains of plants, and this for a considerable depth in the red series, beneath the yellow sandstone of Mr. Griffith, where they have been long known. It is a singular fact in connexion with these gray or bluish beds north of the Hook Point, and one first observed by Captain James in the old red sandstone near Wexford, 25 miles distant, that the greater part of them contain copper more or less disseminated among them in the form of either a blue or green carbonate.

		Ft.	In.
11.	Seams of marl and limestone	0	6
12.	Limestone	0	10
13.	Limestone	0	9
14	Blue marl	1	5
15.	Shale	0	1
16.	Limestone and shale; beds not clearly seen, but the general thickness well ascertained	54	4
	Old Red Sandstone.		
17.	Brown yellow sandstone and red marls	9	0
18.	Coarse yellow sandstone, with ferruginous specks	12	0
19.	Light-coloured sandstone, white in some parts, conglomerate at top; thin bedded; a few ferruginous specks	40	0
20.	Greenish light-coloured conglomerates, with pebbles of quartz and dark siliceous rocks; beds irregular; lower part sandy	28	0
21.	Soft light-coloured and micaceous sandstone	5	6
22.	The same, harder	14	0
23.	Red and light-coloured sandstones intermixed	39	0
24.	Red and light-coloured sandstones intermingled, the latter predominating	72	0
25.	Red and yellowish sandstones	5	0
26.	Hard light-coloured sandstone	4	0
27.	Red marl with greenish blue stripes	34	6
28.	Light-coloured and reddish brown sandstones	36	0
29.	Red sandy marl, slightly micaceous, with greenish blue beds intermixed	27	0
30.	Variegated sandstone, light-coloured, yellow brown, red and greenish blue	53	6
31.	Conglomerate; pebbles of quartz and red sandstone in soft variegated sandstone, red, light-coloured and bluish green	28	0
32.	Red and brown sandstone and conglomerate, a little marl	7	6
33.	Red and light-coloured sandstone	79	0
34.	Red and brown sandstone and conglomerate	25	0
35.	Hard gray sandstone, lower beds brownish gray and brownish red	25	6
36.	Hard red sandstone, with partings of red marl, containing numerous pebbles of quartz and red sandstone	88	0
37.	Red sandstone	45	0
38.	Hard red sandstone beds, with partings of arenaceous red marl; white spots in the sandstone; lower beds conglomerate, pebbles quartz, some red marls	30	0
39.	Coarse soft red sandstone	74	0
40.	Red sandstones, generally coarse and soft, some red marls	874	0
41.	Red sandstone, slightly indurated in part, alternating with some marl (red), greenish blue spots	86	0
42.	The same, false bedding in the sandstones	83	0
43.	Red sandstone and marl, false bedding in the former	150	0
44.	Red sandstone, sometimes with dispersed quartz and other pebbles, marl partings and thin beds full of pebbles, the whole arranged in irregular drifts, so as to form diamond-like sections well seen in cuttings and cliff at the entrance to Ross from Wilton. False bedding common in the sandstones	210	0
45.	Coarse and soft red sandstone, with occasional marls, false bedding in sandstone common. The whole here and there spotted and marked with blue	741	0
46.	Alternations of marls and thin-bedded red sandstones	63	0

	Ft.	In.
47. Alternation of red sandstones and marls	544	0
48. Alternations of red sandstones and marls, some false bedding in the former	441	0
49. Alternations of red sandstones and marls, the latter beginning to predominate	790	0
50. Red marls, sometimes with blue stains, with a few interstratified red sandstones, the sandstones more numerous towards the top . .	601	0
51. Red, with some bluish green marls, alternating with the limestone named '*cornstone*,' three chief beds of the latter	60	0
52. Red, with some bluish green marls containing beds of calcareous nodules	73	0
53. Red marls intermingled with some bluish green, the latter chiefly in beds showing the cylindrical arrangement of this colour in red marl, vertical to the beds, often seen in this part of the old red sandstone in the district. These tubular portions, or rather the tubes being filled cylindrical portions, are sometimes calcareous. A kind of impure cornstone	113	0

Silurian Series.

Section seen near Welsh Court Farm.

54. Brown micaceous and schistose sandstone with carbonaceous spots and traces of plants	6	0
55. Brown marls, with sandstone, similar to the preceding . . .	10	0
56. Brown calcareo-argillo-arenaceous beds. Some bands conglomerate. Very fossiliferous. *Leptæna lata* common	12	0
57. Marls (gray and brown), sometimes arenaceous at top, and in parts micaceous, with irregular bands of limestone. Very fossiliferous. *Leptæna lata*, *Terebratula Wilsoni*, common. Well seen in Welsh Court Farm quarry	32	0

Section continued in Bodenham Quarry, where the last Beds are well seen.

58. Light coloured fuller's-earth, hard bands at top	3	0
59. Argillo-arenaceous beds with nodules of limestone. Marked clean divisional planes. About four chief beds seen. More or less fossiliferous throughout. Good specimens of *Pentamerus Knightii* in the upper bed. Considered equivalent to Aymestry limestone . . .	16	0

This section exhibits the division of the mass into a higher portion, formed chiefly of sandstones and conglomerates, and a lower portion composed principally of marls, intermingled with cornstones, a general mode of occurrence known to geologists by the descriptions of Dr. Buckland, Mr. Conybeare,* and Mr. Murchison.† Of the 5620 feet obtained in this section, the lower 847 may be referred to the marls and cornstones. Comprising the alternations of red sandstones and marls, the latter beginning to predominate, the lower division would have a thickness of 1637 feet.‡

* Observations on the South-Western Coal District of England, Geological Transactions, Second Series, vol. i. p. 284.

† Silurian System, vol. i. p. 170.

‡ A fault may traverse the country, ranging up from Aston Ingham, which may cut off some additional thickness of marl, to the extent, perhaps, of 300 feet. A fault in such a portion of ground, bringing beds of similar mineral character in contact, is difficult to determine.

At first, above the brown micaceous schistose sandstone, No. 54, with its fossils and spots of vegetable matter, a kind of representative, perhaps, of the tilestones of some other localities, the red mud with its calcareous admixture of cornstones and associated green and bluish beds, and without sand, was accumulated to the depth of 246 feet. A kind of deposit, requiring tranquillity, for very slight movement of waters would, before consolidation, have caught it up in mechanical suspension. To this state of things succeeded another, when sand was introduced, occasionally much mixed with the mud, and there was alternate action capable of transporting this muddy sand at one time, and mud only at another; the former, however, in such a manner as not to tear up the surface of the latter to any great extent. The very tranquil deposit gradually became less frequent, and finally, though marls occur with the sandstones, and even the conglomerates in the higher part of the series, the transporting power brought a mass of sand over these first accumulations, gravels finally being intermingled with it.

After a time the sands and gravels would, in a great measure, appear to have been accumulated by the pushing action of water over the bottom, reminding us forcibly of the arrangements effected at the mouths of rivers falling into lakes and tideless seas (p. 9). Sections of this kind of accumulations are common, and the accompanying sketch (Pl. 4) by Captain James, R.E., of the sandstone beds on the rise of the hill from Wilton to Ross, by the turnpike-road, is very characteristic.

The following section of the upper beds of the Old Red Sandstone (not far distant from the section above given), obtained on the new road, north-west from Mitcheldean, on the north side of Dean Forest, by Mr. Trevor James will afford a better view of the detail of these beds, and of their graduation into the carboniferous limestone.

	Ft.	In.
1. Limestones and shales alternating (*fish remains*)	53	0
2. Coarse yellow sandstone (*shells*)	1	6
3. Red marl	2	0
4. Bands of coarse yellow sandstone alternating with red marl	4	6
5. Bands of yellow sandstone and whitish shale alternating (*shales full of plants*)	1	6
6. Coarse yellow sandstone (*plants numerous*)	5	6
7. Greenish shale alternating with bands of sandstone	1	6
8. Red marl	1	6
9. Yellow sandstone and red marls	5	0
10. Yellow sandstone	3	6
11. Coarse yellow sandstone, alternating with whitish shale	24	0
12. Red marl	15	0
13. Greenish sandstones alternating with shale, micaceous	16	0
14. Gray shales and sandstones alternating, very micaceous	15	0
15. Red marl	4	6
16. Greenish sandstone and shales	26	0
17. Coarse gray sandstone	1	6

	Ft.	In.
18. Blue argillaceous shale (*plants*)	1	3
19. Coarse whitish sandstone, lower part conglomerate	1	6
20. Variegated marls	3	6
21. Red marl	10	0
22. Whitish sandstone, micaceous	9	6
23. Coarse red sandstone	41	6
24. Green and red marls	1	6
25. Whitish sandstone	5	6
26. Gray arenaceous shale, very micaceous	3	3
27. Whitish sandstone	8	6
28. Arenaceous shale and marl, alternating	15	6
29. Mica band, *drift mica*	0	4½
30. Whitish sandstone	9	6
31. Red marl	6	0
32. Red sandstone and marl	50	0
33. Conglomerates, generally red, and the pebbles quartz	Not measured.	

From the denudations to which this Old Red Sandstone area has been subjected, the harder and upper beds commonly stand out prominently above the lower, the soft marls having more readily given way to the denuding action which has produced the present superficial form of the country. As a whole, therefore, the lower lands are formed of the marls, or the lower beds, while the hills and mountains, or rather the upper portions of them, are composed of sandstones and conglomerates. Thus the country towards Leominster, Bromyard, Ledbury, and Hereford, is chiefly formed of the marl series with its cornstones, while the Black Forest heights, such as Pen-y-cader-fawr (2345 feet), Mynydd-bychan (2250), Trwyn-llech (2200), and Pen-allt-mawr (2320), are crowned by hard sandstones and conglomerates, in slightly inclined beds, the remains, no doubt, of those which once covered the marls to a greater extent northward.

After circling the coal measures and mountain limestone of the Forest of Dean, the conglomerates and sandstones become separated from those supporting the carboniferous limestone of Monmouthshire and South Wales, by the protrusion of the Uske Silurian rocks, with its skirting of red marls and cornstones, as far down as the neighbourhood of Newport, between which and Cardiff they unite in an arch, with minor flexures, and thence, ranging westward, pass beneath a higher arch of carboniferous limestone near Cowbridge.

On the north of the Monmouthshire, Glamorganshire, and Brecknockshire coal district, with its supporting mountain limestone, the upper part of the Old Red Sandstone forms a range of lofty land, of which the Vans of Brecon attain the greatest elevation, constituting the chief heights of South Wales (2682 feet). From the small angle of dip the continuation of the beds, forming the summits of the Vans, is only a few feet beneath the carboniferous limestone near Merthyr

Tydfil, a limestone which may have covered the upper beds of these Vans, as it does similar beds eastward at Pen-carreg-calch (2250 feet), a mountain rising to the north of Crickhowel. Indeed we can readily imagine a far greater extension of the carboniferous limestone, with its supporting upper portion of Old Red Sandstone over a large adjoining area, Pen-carreg-calch now only affording evidence of the limestone having reached so far northward. Great denudations would easily be effected if this land were so lowered, with respect to the ocean level, that the breakers acted on the soft lower division of the Old Red Sandstone, wearing it away, and causing the higher, harder and slightly inclined beds of sandstones and conglomerates to fall from above into their destructive power. Standing on the Vans of Brecon, and looking northward, the imagination readily fills up the sea to the needful level, a main line of coast ranging, with its bays and promontories, east and west beneath, islands with steep cliffs occurring in the direction of the Black Forest, and of the Cradle and other mountains near Abergavenny. That the denudation has been mainly produced in this manner is far from improbable.

Quitting the area where these accumulations are so well developed, and proceeding westward towards Caermarthenshire and Pembrokeshire, a change becomes observable, and the lower marls, with their associated cornstones, are seen to become gradually more scarce. The Sawdde section, near Llangadock, exhibits the amount of change in a clear manner. Though cornstones are still seen in it, they are scarce, and sandstone is mingled with the marls, so that the former is in nearly equal abundance with the latter. Not only do we appear to find a mingling of sand more at the same geological time westward than eastward, reminding us of that previously noticed in the Silurian deposits, but also an overlap of the higher arenaceous and conglomerate series upon the lower and marly accumulations; the commencement of that system of overlap which more westward brings the various accumulations of the old red sandstone, the carboniferous limestone and the coal measures over the lower Silurian rocks, and which, still further westward, in the opposite parts of Southern Ireland, amounts to the superposition of the old red sandstone, with its covering of carboniferous limestone and coal measures, upon the upturned and highly inclined beds of Silurian rocks.

The sandstone and conglomerate portion of the Old Red Sandstone, as this rock occurs in Herefordshire, thus seems to cross over the marls beneath, so that sandstones constitute the lower beds near Caermarthen and thence along the northern edge of the Old Red Sandstone westward towards Slebech.

In the following section, one in which we should expect to find more

marls in the lower part, than at Llandilo and Caermarthen, from being, as it were, a view opened by denudation into a part several miles within the edge of the overlap in Pembrokeshire, we still discover only a small thickness of such marls, even adding, as a base, the whole of those with their accompanying calcareous portions, seen at Freshwater East.

Section of Carboniferous Limestone Lower Shales, and of the Old Red Sandstone between West Angle Bay and Freshwater West, Pembrokeshire.

Carboniferous Limestone Shales. West Angle Bay.

		Feet.
1.	Calcareous shales, with nodules of limestone	8
2.	Calcareous shales, with a few bands of limestones	85
3.	Calcareous shale, with bands of limestone	104
4.	Limestone with shale (*Encrinites*)	6
5.	Calcareous shales, with limestone bands	115
6.	Sandy limestone, alternating with shales (*Belerophons*, &c.)	14
7.	Nodular limestone beds	12
8.	Shales	6
9.	Nodular limestone	18
10.	Shales and hard limestone	34
11.	Shales	68
12.	Sandy limestone	3
13.	Shales, with calcareous bands	16
14.	Sandstones (containing calcareous matter) with yellowish shales	19
15.	Arenaceous shales	16
16.	Bluish arenaceous shales, with two thin red bands	17
17.	Soft red bed, with pebbles of quartz	3
18.	Yellow and flaggy sandstone	15
19.	Sandstones, with some shale	9
20.	Shales, with calcareous bands and nodules, and sandstone bands	16
	Old Red Sandstone.	
21.	Red shales	25
22.	Alternations of gray and red sandstones	41
23.	Conglomerate	2
24.	Gray sandstone and bluish marl	25
25.	Red and gray sandstone	29
26.	Red marls	15
27.	Red conglomerate	2
28.	Red marls	58
29.	Red sandstone and marls	19
30.	Red and gray sandstones	91
31.	Red sandstones	145
32.	Red sandstone, becoming thick bedded	828
33.	Red sandstone, and red arenaceous shale	190
34.	Red sandstone, interstratified with a little shale	346
35.	Red marl, with some sandstone	130
36.	Red sandstone, with some interstratified gray sandstones	560
37.	Red and gray sandstones, with some marls	296
38.	Gray sandstone and red marls	154
39.	Red marls and sandstones, with gray sandstones, chiefly the former	496
40.	Red sandstone	346
41.	Red marls, with some sandstones	77

The base of the section is not seen; but judging from the section in Freshwater East (p. 54), a short distance only intervenes between the beds last mentioned and the Silurian rocks, the intermediate depth chiefly occupied by red marls, with traces of cornstones. We may consider much of the valley at the back of Freshwater West as having been hollowed out in these marls, offering, as they would, upon a slight difference of the present level of sea and land in that locality, but little resistance to the action of the Atlantic breakers.

The following section will afford a view of the mode of occurrence of the upper part of the same range of beds as those noticed above between West Angle and Freshwater West, within a distance of eighteen miles.

Section of the Lower part of the Carboniferous Limestone, and of the Upper of the Old Red Sandstone, at Caldy Island, near Tenby.

Lower beds of Carboniferous Limestone.

	Feet.
1. Limestone beds, from 7 to 8 inches or 1 foot thick, abounding in *Encrinites*, being chiefly composed of their remains. Many *Spiriferæ* also	400
2. Limestone and shales	30
3. Thin-bedded limestone	16
4. Shales, with a few beds of limestone	12
5. Shales, containing calcareous matter	37
6. Thin-bedded argillaceous limestone	26
7. Limestone, chiefly thick-bedded	95
8. Slaty and yellowish, slightly coherent sandstone	67
9. Brown shales, with a few bands of impure limestone	29
10. Brown, fossiliferous, argillo-arenaceous beds	90
Old Red Sandstone.	
11. Brownish red conglomerate; quartz pebbles	6
12. Soft marly ground	4
13. Brownish conglomerate, chiefly quartz pebbles	7
14. Yellowish sandstone, with a few quartz pebbles	5
15. Red marls and sandy marls, with a few yellow stripes	50
16. Thin band of hard, siliceous sandstone	
17. Red marls, with arenaceous and harder beds	75
18. Hard siliceous sandstones, with some softer beds	30
19. Conglomerate, chiefly quartz pebbles	9
20. Slaty red sandstone	3½
21. Hard siliceous sandstone, with some quartz pebbles	4
22. Thick and thin bedded brownish-red sandstones	14
23. Hard siliceous and reddish brown sandstone, with quartz pebbles	6
24. Red marls	12
25. Hard reddish sandstone, with pebbles	5
26. Red marls	9
27. Hard sandstone, conglomerate	3
28. Red marls	47
29. Red sandstone	13
30. Red marls	96
31. White, quartzose, thin-bedded sandstones	36
32. White and red thin-bedded sandstones	13

		Feet.
33.	Slaty and marly red sandstones	37
34.	Red sandstones, with some, though not much, red marl	350
35.	Alternations of red marl and sandstone	300
36.	Red sandstone, with some variegated beds and some marls	610
37.	Impure limestones, *cornstones*, mottled red and blue, intermixed with sandstones and marls, forming the extreme point south from the lighthouse	56

Cornstones would appear much higher in this section than in the preceding, where they are confined to the lower beds. In other localities, even within a moderate distance, as, for instance, near Pembroke, they are found still higher. The following is an analysis made by Mr. Trenham Reeks, at the Museum of Economic Geology, of one of numerous cornstone nodules disseminated in red marl among the conglomerates in the upper part of the old red sandstone at Pembroke Creek, Milford Haven, and may serve as an average view of the composition of cornstones, one which varies considerably:—

Carbonate of lime	69·3
Peroxide of iron	2·2
Silica	19·5
Alumina	7·2
Water	0·9
Traces of chlorides, sulphates, and loss	0·9
	100·0

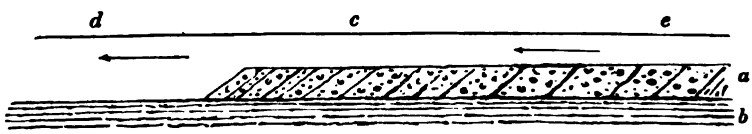
The red marl in which the cornstone nodules occur was found by Mr. Trenham Reeks to consist of the following substances, and the analysis is interesting as showing the trifling quantity of carbonate of lime in the marl, though so full of impure limestone, apparently concretions separated from it after the deposit of the whole.

Silica	64·3
Alumina	21·1
Peroxide of iron	9·6
Carbonate of lime	0·2
Water	4·5
Traces of chloride of sodium, and loss	0·3
	100·0

Conglomerates are seen in the last and the preceding section to be found in the upper parts, a fact observable from the neighbourhood of Ross, in a distance of 110 miles, and one sufficient to show a very common cause for the formation and accumulation of gravel beds at that geological period. Though sometimes exhibiting the diagonal arrangements that mark the action of water pushing the detritus along the bottom, these conglomerate beds which, without being strictly continuous for considerable distances, still keep a fair geological horizon, do not resemble beaches. In situations where they can be

traced round various hills, over an area of several square miles, as, for example, on the mountains composing the Black Forest and adjoining heights of the Vans of Brecon, they present good parallel planes, above and beneath, showing very even accumulations (more resembling the filling up of a sudden depression of a few feet by water), moving with the requisite velocity, and fed very constantly with gravel and sand, as in the figure beneath (Fig. 12), where *a* is a conglomerate bed, thus forming over *b* by the movement of the water *c*, in the direction *d*, constant additions of gravel and sand being supplied from the side *e*.

Fig. 12.



That during the accumulation of the Old Red Sandstone, beds of sand became consolidated is evident; for among the pebbles of the conglomerates, rolled pieces of the red sandstones, resulting from such consolidation of the sand, are found. The chief pebbles are, however, rounded pieces of veinstone quartz, the sandstones more rarely, it would seem, having been sufficiently hard to resist the friction to which fragments of them have been exposed. The quantity of quartz distributed as pebbles among the conglomerates is collectively considerable; and as the quartz generally presents the appearance of that filling veins and cracks, considerable destruction of the rocks in which veins and cracks, so filled, occurred, seems required to afford the quartz. In many localities at the present day, where soft rocks are traversed by quartz veins, adjacent beaches are composed of little else than quartz pebbles, and rivers traversing a similar country, particularly if the falls be somewhat rapid, will bring down an abundance of such pebbles, so that not only may the quartz pebbles have been derived from veins in older slate rocks, but from those in pre-existing beds of the Old Red Sandstone itself, since we have seen that there is evidence of such having been broken up, furnishing a part of the materials for newer strata, and mingled with the quartz in the same beds of conglomerate.

In the Old Red Sandstone of the Mendip Hills, and of the vicinity of Bristol, where the upper beds rise through the carboniferous limestone, conglomerates of the like kind are observable, and the same are seen emerging from the carboniferous limestones of Gower, near Swansea; so that over an area of about 3000 square miles, the same general causes, producing similar effects, were in action at this geological period, one which preceded a very different state of things over

a great proportion of it. Pebbles even of the size of walnuts, such as many of them are, some being of far larger dimensions, would require a fair velocity of water to move them. The mixture of marls, sandstones and conglomerates, towards the upper part of the Old Red Sandstone, marks very unequal minor action of the necessary causes at that time, and yet, the general action, taken as a whole, produced a certain uniformity over a wide area.

As to the origin of this mass of detritus, for such it probably is, with the exception of the impure limestones (cornstones), the destruction of granite rocks, in the sense formerly used, with the addition of the iron, could readily furnish the chief part; quartz, mica, and decomposed felspar or albite (as clay or marl), constituting the principal portion of it. Some of the Silurian deposits, again worn away and used, may have supplied a part, in the same manner that in the conglomerates of that time we find pieces of Silurian rocks, and in those of the Old Red Sandstone, portions of lower beds of the same series. In fact, as soon as beds became consolidated and were exposed to destructive influences, as they seem speedily to have been, speaking geologically, by portions of extensive deposits being brought within the power of breakers, or up into the atmosphere, by repeated changes in the relative levels of land and sea over different areas, parts of older detrital rocks were worked up again into more modern accumulations, in addition to a supply from pre-existing rocks formed by igneous fusion, or deposited from chemical solutions in water.

It might, perhaps, have been desirable to have deferred a notice of the older rocks of Cornwall and Devon, to which Professor Sedgwick and Mr. Murchison have assigned the name of *Devonian System*,* if this term had not of late been employed as a complete equivalent of the beds mentioned above, under the head of Old Red Sandstone; inasmuch as in Cornwall and Devon there may be equivalents both of the carboniferous limestone above, and of the higher parts of the Silurian rocks beneath, also included in this system, such as it has been defined in these two counties.

After a variety of opinions expressed as to the geological age of the limestones intermingled with the slate rocks of South Devon, Mr. Lonsdale inferred, in 1838, from an examination of several fossils from these limestones, that they were probably equivalent as deposits to some part of the Old Red Sandstone series; the organic remains detected in them being partly of the same species with some found in the Silurian rocks, partly with others discovered in the carboniferous limestone, and partly

* On the Physical Structure of Devonshire, and on the Subdivisions and Geological Relations of its older stratified Deposits, &c. Geological Transactions, Second Series, vol. v. p. 701.

peculiar.* This view was, in 1839, extended by Professor Sedgwick and Mr. Murchison, to all the fossiliferous slate rocks of Cornwall and Devon, older than the Devon *Culm Measures* of the same geologists.† At the same time they pointed out the absence of a good geological base line for the latter deposits, noticing also the "extreme difficulty in

* Notes on the Age of the Limestones of South Devon. Geological Transactions, Second Series, vol. v. p. 727.

A very complete list of the varied opinions on this subject, which necessarily more or less depended on the knowledge of the day, is given by Mr. Lonsdale, with his characteristic desire of accuracy, and extend from that of Woodward, in 1729, to those of Professor Sedgwick and Mr. Murchison, in 1839 (p. 721–725.)

He observes, that it was immediately after a communication of Mr. Austen to the Geological Society, in December 1837, that he "formed the opinion relative to the limestones of Devonshire being of the age of the Old Red Sandstone," communicating this opinion, first to Mr. Murchison, then to Professor Sedgwick, and subsequently to other members of the Geological Society and myself, in 1838 (p. 724).

The following contains the views he took on the subject:—"It has been already mentioned that the suggestion was first proposed in December, 1837. I had previously examined in part the corals of the Silurian System and of South Devonshire, and satisfied myself that some of the species are common to both. I had also examined with Mr. James Sowerby, on its first arrival in London, Mr. Hennah's valuable collection of fossils (from the Plymouth Limestones), and had become aware, by the remarks of Mr. Sowerby, that certain of the shells, found near Plymouth, could with difficulty, if at all, be distinguished from mountain limestone species, and that some were distinct. Immediately after the reading of Mr. Austen's paper in December 1837, I had the pleasure of examining with that gentleman a part of his collection; and though I ventured to dissent from some of the identifications with mountain limestone shells pointed out to me (*Pleurorhynchus minax*, *Terebratula acuminata*), yet the fossils agreed so much in aspect with Testacea of the Carboniferous Fauna, that it was impossible to doubt, that the beds from which the specimens had been obtained, had some connexion with the mountain limestone system. From an examination of the collection, I also ascertained that in the same limestones with these shells, occur corals common to the Silurian System. Through the kind communications of Mr. Austen, I had likewise become aware that the *Calceola sandalina*, a shell previously obtained only from districts on the Rhine, and considered to be transition, existed in Devonshire in beds associated with the limestones; and that he had obtained many new cephalopods and other fossils from the same districts."

"It was therefore by combining together this evidence—the presence, in the same series of beds, of shells resembling or identical with mountain limestone species, of Silurian corals, the *Calceola sandalina*, and various distinct testacea—that I was induced to suggest that the South Devon limestones are of an intermediate age between the Carboniferous and Silurian Systems, and consequently of the age of the Old Red Sandstone. It is necessary to add, that Mr. Murchison had shown that there is a regular passage from the Old Red Sandstone upwards into the Carboniferous system, and downwards into the Silurian, and that the suites of fossils of the two systems are perfectly distinct." (p. 727.)

† On the Physical Structure of Devonshire, and on the Subdivisions and Geological Relations of its older stratified Deposits, &c., part ii. Geological Transactions, Second Series, vol. v. p. 691. They observe, "Guided then by the evidence already stated, and the conclusions to which it seemed to point, we have re-examined the fossils obtained, either by our own labours or the assistance of our friends, from the two counties; and the conclusion arrived at by Mr. Lonsdale respecting the age of the South Devon limestone, we now apply, without reserve, both to the five groups of our North Devon sections and to the fossiliferous slates of Cornwall."

the northern parts of our island, of drawing any precise line of demarcation between the base of the coal measures and the old red sandstone."*

This difficulty does not appear to be lessened when we have to consider the probable geological age of the range of beds immediately beneath the deposits termed *Culm Measures*, especially in North Devon; and such must be expected when exact equivalents, in geological time, are sought among accumulations which have been governed by physical conditions in one part of a given area, different from those in force in another. Under such circumstances also, we should avail ourselves of the organic forms, discovered in the deposits with much caution, since, as is now well understood, such forms being adapted to conditions, we may, in nearly approximating geological times, easily have some of these forms higher in the order of accumulations in one place than in another. We have also to consider, when estimating the value of any particular mixture of forms, the continuance of particular conditions favourable for the uninterrupted existence of certain animals and plants, and unfavourable to others, always carefully bearing in mind the general great change in the organic life observed in the deposits effected during a long lapse of geological time, the evidence of which these minor differences would by no means effect, but rather confirm, seeing that by natural causes it is difficult to conceive any general changes which should not be accompanied by such modifications.

As Professor John Phillips very truly observes, "taken without limitation, the proposition, that 'strata are of the same age because they contain the same organic remains,' assumes that the period of existence, on the land or in the sea, of the species which are thus treated, was exactly the same in all situations where they appeared." And he proceeds to observe, that "this is not very probable, for in existing nature we find the distribution of species related to particular geographical centres, from which they may be supposed to have spread; and in a fossil state we find certain forms of life prevalent in one part of a group of strata in one district, and in a different part of the same in another.†

Considerations of this kind, and indeed a proper application of the knowledge of the conditions under which existing animal and vegetable life is distributed, have lately much engaged the attention of geologists, and are essential when we seek to refer given calcareous or detrital

* On the Physical Structure of Devonshire, and on the Subdivisions and Geological Relations of the older stratified Deposits, &c. part ii. Geological Transactions, Second Series, vol. v. p. 694.

† Figures and Descriptions of the Palæozoic Fossils of Cornwall, Devon, and West Somerset (1841), p. 163. Professor Phillips adduces as a good example the *Orthis Hardrensis*, "which, in Yorkshire, lies *above*, and, at Bristol, lies *below* the great mass of mountain limestone."

accumulations, by the aid of organic remains, to the same geological time with others.*

It will be obvious that if such centres of particular animal forms occurred in early geological periods as are considered to be now found, some amount of time must have elapsed before these forms became diffused, and even then only in localities favourable for their existence. Hence, even allowing representative species to have been abundant, when we compare far distant areas with each other, no little caution is needed in drawing boundary lines, vertically, amid masses of varied accumulations in one place, and in assigning very exact equivalents to them, in geological time, among the deposits of another. With any reference to the distribution of land and water in early geological times, and the power of obtaining the detrital accumulations in which so many animal remains are entombed, in a manner at all resembling that which we now observe, such very exact minor equivalents cannot be expected.

It may be very convenient to employ given names, adopted in districts where changes and marked interruptions of deposits fully justify them, as far as such changes or interruptions are continued, but where these rocks merge into other kinds of accumulations, marked by more modified changes, and a continued sequence of similar deposits, it may be very much doubted how far science is really advanced by the practice of splitting up the latter into parts, often in a most arbitrary manner, to meet the divisions considered advisable in the first district. Certainly it is desirable to carry out our views of the state of large surfaces at given geological periods, as far as possible, by the aid of the artificial divisions we may conveniently establish, in the lapse of geological time, in a sequence of different deposits over a known area; but these divisions should not be too limited, and the various natural causes, as well for the mineral accumulations as for the distribution of organic remains in them, vertically and horizontally, should be well borne in mind. Organic forms, considered characteristic of one locality, should be viewed with reference to the conditions under which they occur, and no surprise

* Mr. Lonsdale, while reasoning on the probable equivalents of the South Devon limestones, and pointing out the value of organic remains in determining the relation of age of the deposits containing them, was well aware of the importance of such considerations. "I beg, however," he observes, "it may be clearly understood, that in advocating the value of fossils, I would not expunge from the geologist's consideration the aid to be derived from order of superposition, and, under a right control, from the use of mineral composition and lithological structure. I would also advise him not to depend upon his own limited sources of knowledge, but to seek the aid of the philosophical zoologist, who can teach him to reason justly on the distribution of animal life—the accidents to which it is liable—the changes which such accidents may produce, or the means provided by nature to resist them—and on the effects which a permanent alteration in the inhabiting medium may work on the form and size of a shell or coral."—Geological Transactions, Second Series, vol. v. p. 730.

need be experienced either at not discovering them in the same geological range of deposits, where these conditions have not obtained, or at even finding them somewhat higher or lower amid accumulations where the same circumstances have prevailed.*

In the present instance we have not to compare far distant accumulations, but, on the contrary, those removed only a few miles from each other; hence, viewing the Devonian System as an equivalent of the Old Red Sandstone, we have to consider the differences or resemblances of deposits effected during a long lapse of time, several thousand feet thick, and at no great distance horizontally from each other.

The first obvious difference is observed in the colour of the two masses. While an abundance of peroxide of iron characterizes the one, this substance is far less prevalent in the other. This at once leads us to expect that the amount of organic remains discovered in the latter may bear some kind of proportion to the absence of peroxide of iron from it, and consequently, that some of the marine animals found in the Silurian accumulations of South Wales may have continued to exist in the next succeeding deposits in Devon and Cornwall, equivalent in geological time to the Old Red Sandstone of the former.

We now, however, arrive at the difficulty of artificial boundary lines, which may be geologically useful. Some embarrassment was experienced (p. 46) as to a really good line of demarcation between the Silurian rocks and Old Red Sandstone in South Wales and Herefordshire, but after a time, the prevalence of mud and sand, abundantly charged with peroxide of iron, gained so exclusively over other deposits of the time, that the vertical depth is comparatively small wherein the difficulty is experienced, so that after a minor lapse of time the crustaceans, molluscs, and corals requiring contact with the sea bottom were completely driven away, and fishes only under peculiar conditions found their way into the seas above.

When we compare the accumulations of North Devon and West Somerset beneath the range of beds, which includes patches or lenticular masses of limestone, extending from Combe Martin, by Kentisbury, Challacombe, Exford, to Luxborough, and curving round thence by Tre-

* Though compelled in geological maps, particularly those on a moderate scale, to generalize by colours, so as to represent by the same tints those deposits which have been formed in equal geological times, we should be careful to show by sections of sufficient detail and magnitude, all the changes and modifications found, so as to assemble a mass of facts available for a proper consideration of the manner in which the accumulations may have been effected, carefully noticing the mode in which organic remains may occur, as well regarding horizontal distribution at equal geological times, as vertically in the series. In the large, and separately published, vertical and horizontal sections of the Geological Survey of the United Kingdom, it is attempted, as much as possible, to effect this desirable object.

borough to Withycombe, we find a considerable amount of deposits which lithologically differ but little from the upper portion of the Old Red Sandstone of Herefordshire and Monmouthshire, and more especially that portion of the same series as seen in Pembrokeshire, among which brown and gray beds are more common than on the east. With the exception of the gray fossiliferous beds of Linton, there is much to remind us of the Old Red Sandstone as developed in the localities above mentioned. At the Foreland, near Linton, we find red, gray, and brown sandstones, frequently coarse-grained, associated with slates of the same tints, among which red is the most marked, and above the fossiliferous beds of Linton, deposits of a very similar character; so that these fossiliferous deposits are included in a mass of accumulations, among which red and claret-coloured slates, or detritus highly charged with peroxide of iron, are very prevalent.*

Professor Phillips estimates the included fossiliferous gray beds of Linton, at about 1000 feet thick. The character of the organic remains in such a deposit, included among rocks containing much peroxide of iron, and bearing a general resemblance to the upper portion of the Old Red Sandstone at no great distance on the north and on the north-eastward (in the Mendip hills and near Bristol), becomes interesting. By reference to Professor Phillips' list, we see that (1.) *Turbinolopsis pluriradialis*, (2.) *Favosites polymorpha*, (3.) *Fenestella antiqua*, (4.) *Actinocrinus? tenuistriatus*, (5.) *Pterinea spinosa*, (6.) *Orthis sordida*, (7.) *O. longisulcata*, (8.) *O. granulosa*, (9.) *O. compressa*, (10.) *Spirifera osteolata*, (11.) *Sp. aperturata*, (12.) *Pleurotomaria aspera*, (13.) *Bellerophon globatus*, and (14.) *Orthoceras Ludense*, are mentioned as found in this group of beds. To which should be added, from the lists of Professor Sedgwick and Mr. Murchison, (15.) *Favosites fibrosa*; † of these, Nos. 2, 9, 13, 14, and 15, are noticed as also found in the Silurian rocks, and No. 10 in carboniferous limestone.

Since these lists were published, Mr. Griffith, in his view of the horizontal and vertical distribution of the carboniferous limestone fossils in Ireland‡ states, that Nos. 1, 2, 3, 4, 7, 8, 9, 10, 11, and 13, or 10 species, are discovered in the lower part of the carboniferous limestone series of that country; so that assuming the determination of the

* Detailed accounts of the North Devon rocks, and of the other deposits of the same geological age in Cornwall, Devon, and West Somerset, will be seen in the Memoir on the Physical Structure of Devonshire, &c., by Prof. Sedwick and Mr. Murchison, Geological Transactions, Second Series, vol. v.; in Prof. Phillips' Figures and Descriptions of the Palæozoic Fossils of Cornwall, Devon, &c. (1841), and in the Ordnance Geological Survey Report on the Geology of Cornwall, Devon, and West Somerset (1839).

† Geological Transactions, Second Series, vol. v. p. 703.

‡ Notice respecting the Fossils of the Mountain Limestone of Ireland, as compared with those of Great Britain, and also with the Devonian System, Dublin, 1842.

species to be correct, the chief zoological character of the Linton beds, which at first appeared to be Silurian, would be that of the carboniferous limestone.

Above the gray and red sandstones and slates, so well exhibited in sections on the coast, at the Great and Little Hangman Hills (respectively 1083 and 756 feet in height), we find gray argillaceous slates, often calcareous, with the included limestones of Combe Martin, and other places mentioned above. These argillaceous slates and limestones, with sandstones, sometimes calcareous and fossiliferous, extend on the coast beyond Ilfracombe, and constitute the Ilfracombe system or group of Professor Sedgwick and Mr. Murchison,* and of Professor Phillips.†

The following organic remains are noticed in these beds by Professor Phillips:—(1.) *Cyathophyllum cæspitosum*, (2.) *Cystiphyllum Damnoniense*, (3.) *Strombodes vermicularis?* (4.) *Favosites polymorpha*, (5.) *F. fibrosa*, (6.) *Millepora similis*, (7.) *Fenestella arthritica*, (8.) *Cyathocrinus variabilis*, (9.) *Strigocephalus Burtini*; of these, Nos. 1, 4, and 5, are mentioned as also discovered in the Upper Silurian Rocks. To this list we have to add the following from that of the Devonian and Cornish fossils by Professor Sedgwick and Mr. Murchison:‡—(10.) *Cyathophyllum quadrigeminum?* (11.) *Astrea helianthoides*, (12.) *A. Hennahi*, (13.) *Porites pyriformis*, and (14.) *Spirifera inornata*; of these, No. 13 is noticed as discovered in the Silurian rocks. In the lists of Mr. Griffith,§ Nos. 4, 5, 6, 8, and 14, are noticed as discovered in the lower part of the carboniferous limestone series of Ireland. So that out of the 11 species of corals enumerated, 2 species are represented as common to the Silurian System and lower carboniferous limestone series, 2 to the Silurian rocks, and 1 to the carboniferous limestone. One crinoid (No. 8) is stated to be discovered in the lower carboniferous limestone series in Ireland, and one brachiapod (No. 14) in the same zoological position. Hence the chief zoological character of this very limited catalogue of organic remains would be that of the lower carboniferous limestone series.

Viewed as a whole, without reference to Mr. Griffith's list, and as far as the other evidence extends, the lower beds of the North Devon section would exhibit no very marked mixture of carboniferous and Silurian fossils, the organic remains determinable being chiefly corals, in the upper or Ilfracombe group, of which nearly one-third are also said to be found in the Silurian series. In the lower, or Linton group, 2 out of 4 corals determined are Silurian, as also 3 out of the 10

* Geological Transactions, Second Series, vol. v. p. 642.

† Figures and Descriptions of the Palæozoic Fossils, &c., p. 165.

‡ Geological Transactions, Second Series, vol. v. p. 703.

§ Notice respecting the Fossils of Mountain Limestone of Ireland, &c.

molluscs. Among the 13 corals, 2 crinoids, and 12 molluscs, together 27 species, noticed as determined in the fossiliferous groups of Linton and Ilfracombe, one shell only, *Spirifera osteolata* is mentioned as discovered in the carboniferous limestone. As far, therefore, as regards the lowest mass of the North Devon rocks, several thousand feet thick, and we might here add, the Morthoe argillaceous slates, and the red, brown and gray arenaceous beds of Pickwell Down,* there would be no great evidence of a mixture of the animal forms observed in the carboniferous series with those of the Silurian System, while out of the same 27 species, 5 corals and 3 molluscs, together 8 species, are referred to forms discovered in the latter.

The lists of Mr. Griffith would considerably change the reasoningon this subject; for according to them, out of the 13 species of corals in the Linton and Ilfracombe groups, 2 are common to the Silurian and Carboniferous series, 2 others are found in the Silurian, and 2 more in the Carboniferous series. Of the 2 crinoids, both are abundantly found in the lowest part of the Irish Carboniferous limestone series. Of the 9 conchifers, one (*Orthis compressa*) would be common to the Silurian and Carboniferous series, and 6 others are noticed as discovered in the lowest part of the Carboniferous series of Southern Ireland. Of the 3 gasteropods, one (*Bellerophon globatus*) would be common to the Silurian and Carboniferous series, and 1 other referable to the Silurian rocks. Taking the whole 27 species, 4 would be common to the Silurian and Carboniferous series, 3 others would be found in the former and 10 in the latter, so that the general zoological character would chiefly approximate to the Carboniferous limestone of Ireland.

Including the Morthoe and Pickwell Down beds, we have a considerable thickness of deposits to the bottom of the Foreland accumulations, marked by the presence of peroxide of iron in sufficient abundance at the base, the centre, and the top, to give a red colour to a large amount of beds, in a manner reminding us of the Old Red Sandstone accumulations on the north and north-east; these three divisions, thus characterised, being separated from each other by detrital and calcareous deposits of considerable thickness, calcareous matter being most abundant in the highest.

In the intermediate divisions organic remains are discovered, marking the presence of marine life, chiefly of a kind differing from that known as having existed during the Silurian epoch on the north, yet still showing that corals and molluscs living at that period, existed here also during the time that the rocks of North Devon were accumulating. Thus neither lithologically or zoologically is there any difficulty in

* See Geological Report of the Geology of Cornwall, Devon, &c. plate iii. section 1.

agreeing with Professor Sedgwick and Mr. Murchison that at least up to the higher red beds of Pickwell Down (beds well marked in their range from the coast eastward to Main Down,* near Wiveliscombe, a distance of 40 miles), the North Devon rocks may be equivalent, in geological time, to some part of the Old Red Sandstone, as developed in Herefordshire and other adjoining districts, more especially to its higher portion.

In the ascending order we next arrive at a mass of beds, the lower of which are arenaceous, chiefly schistose, and frequently micaceous, and in them plants are found. Above these occur argillaceous slates, intermingled with arenaceous beds, calcareous matter being occasionally found in both. To this deposit succeed argillaceous slates, often calcareous in the higher part, sufficiently so on the east towards Dulverton to form limestone beds.

This mass of accumulations, collectively one of considerable thickness, constitutes the fifth group of Professor Sedgwick and Mr. Murchison,† and the Pilton group of Professor Phillips.‡ Respecting it the latter geologist observes, "Altogether this series has yielded by far the largest proportion of the fossils of North Devon; and it is probable that further research would at once discover many more species, and prove the nearly uniform character in respect to organic contents of the whole range of the same beds. Observable differences, however, mark the different sorts of rock; thus it is in the sandstone beds of Marwood that principally occur the supposed Cucullеæ and Cypricardiæ; in the slaty and thin gritty beds of Pilton and Brushford lie Trilobites and *Spirifera calcarata*; while in the thin limestone bands and nodules of Baggy Point many other forms appear, but most of those above mentioned are absent."§

Professor Phillips in his synopsis of species and geographical distribution in the Palæozoic rocks of Devon and Cornwall,‖ enumerates the following as discovered in the Pilton group:—Polypiaria: (1.) *Turbinolopsis celtica*, (2.) *T. pluriradialis*, (3.) *Manon cribrosum*, (4.) *Mille-*

* See Geological Report, &c., plate iii. section 2.

† Geological Transactions, Second Series, vol. v. p. 643.

‡ Figures and Descriptions, &c., p. 186.

§ Figures and Descriptions, &c., p. 186. Professor Phillips proceeds to observe:—"This variation of organic forms, according to the mineral nature of the deposit, has been recognised in every system of stratified rocks; it contributes at once to demonstrate the residence on the spot where they now occur of the species which are buried, and to confirm in detail that dependence of the occurrence of organic forms *on co-existent local physical conditions*, which cannot be overlooked on a large scale, in the alternations of fossiliferous and non-fossiliferous strata so remarkable in North Devon—a dependence which the analogy of existing nature teaches us to expect and to search for; but which, though recognised by every careful observer, has been too little regarded in geological reasoning."

‖ Ib. p. 142–153.

pora gracilis, (5.) *Glauconome bipennata*, (6.) *Fenestella laxa*, (7). *F. antiqua*. Crinoidea :—(8.) *Pentremites ovalis*, (9.) *Cyathocrinus macrodactylus*, (10.) *Adelocrinus hystrix*, (11.) *Actinocrinus? tenuistriatus*, (12.) *Cyathocrinus? pinnatus*, (13.) *Cy. variabilis*. Conchifera :—(14.) *Sanguinolaria lirata*, (15.) *Pullastra antiqua*, (16.) *P. complanata*, (17.) *Cypricardia impressa*, (18.) *Nucula plicata*, (19.) *N. lineata*, (20.) *N. latissima*, (21.) *Cucullæa amygdalina*, (22.) *Cu. Hardingii*, (23.) *Cu. angusta*, (24.) *Cu. unilateralis*, (25.) *Cu. trapezium*, (26.) *Pecten polytrichus*, (27.) *P. transversus*, (28.) *Avicula cancellata*, (29.) *Av. rudis*, (30.) *Av. Damnoniensis*, (31.) *Leptæna analoga*, (32.) *Lep. convoluta*, (33.) *Lep. scrabicula*, (34.) *Lep. caperata*, (35.) *Lep. membranacea*, (36.) *Orthis interlineata*, (37.) *O. plicata*, (38.) *O. parallela*, (39.) *O. compressa*, (40.) *O. calcar*, (41.) *O. semicircularis*, (42.) *Spirifera microgemma*, (43.) *Sp. unguiculus*, (44.) *Sp. decussata*, (45.) *Sp. calcarata*, (46.) *Sp. disjuncta*, (47.) *Sp. obliterata*, (48.) *Sp. rudis*, (49.) *Sp. mesomala*, (50.) *Sp. megaloba*, (51.) *Terebratula laticosta*, (52.) *T. pleurodon*. Gasteropoda :—(53.) *Acroculia vetusta*, (54.) *Euomphalus serpens*, (55.) *Natica meridionalis*, (56.) *Pleurotomaria cancellata*, (57.) *Pl. aspera*, (58.) *Pl. expansa*, (59.) *Pl. gracilis*, (60.) *Loxonema rugifera*, (61.) *Murchisonia angulata*, (62.) *Macrocheilus neglectus*. Cephalapoda :—(63.) *Bellerophon Urii*, (64.) *B. trilobatus*, (65.) *B. globatus*, (66.) *Orthoceras Ludense*, (67.) *O. imbricatum*, (68.) *O. lineolatum*, (69.) *O. tentaculare*. Crustacea :—(70.) *Calymene accipitrina*, and (71.) *Cal. lævis*.*

When we compare this list with that of the fossils noticed in the North Devon deposits beneath, we find no correspondence in the corals, except in two instances, *Turbinolopsis pluriradialis* and *Fenestella antiqua*, and no mention is made of any corals found in the Silurian rocks of South Wales, Herefordshire, and Shropshire, four species of which were described as obtained in the lower accumulations of North Devon. Of the Crinoidea, two species are common to the upper and lower divisions of the North Devon deposits, and none are referred to species of the Silurian rocks. Of the Conchifera, two species, *Orthis interlineata* and *Orthis compressa*, are common to the two divisions, the latter being also found in the Silurian rocks. Of the Gasteropods one species, *Pleurotomaria aspera*, is common to the upper and lower divisions. Of the Cephalopods, two species are found in both, *Bellerophon globatus* and *Orthoceras Ludense*, each also discovered in the upper Silurian rocks.

Of the 71 species mentioned by Professor Phillips as occurring in the Pilton group, 17 are stated by him to be detected in either the Silurian rocks or carboniferous limestone, Nos. 16, 17, 39, 41, 64, 65, 66, and

* *Orthoceras cylindraceum*, mentioned as having been found doubtfully at Baggy Point, is omitted from this list.

68 (8 species) in the former, and Nos. 6, 31, 33, 52, 58, 60, 61, and 63 (8 species) in the latter; one species, No. 53, *Acroculia vetusta*, being regarded as common to both.

To these fossils of the upper division of the North Devon rocks should be added, from the lists of Professor Sedgwick and Mr. Murchison, (72.) *Terebratula acuminata*, (73.) *T. oblonga*, (74.) *T. indentata*, (75.) *T. striatula*, (76.) *Leptæna prælonga*, (77.) *Spirifera extensa*, (78.) *Avicula pectenoides*, (79.) *Pecten nexilis*, and (80.) *P. arenosus*. Of these Nos. 72 and 81 occur in the mountain limestone of Yorkshire.

The mass of these species is thus, according to these lists, not noticed as found either in the Silurian rocks or in the mountain limestone; and of the few mentioned as discovered in either of these rocks, the numbers are nearly equal. From this zoological character the upper division of the old North Devon rocks has also been referred to the date of the Old Red Sandstone, and consequently to some higher portion than the inferior accumulations comprehended between the Morthoe and Foreland beds, both inclusive. The upper portion of the Old Red Sandstone of South Wales, Herefordshire, Monmouthshire, Gloucestershire, and Eastern Somerset, has a very common character, one of conglomerates and sandstones, marls being subordinate, all in a great measure loaded with peroxide of iron. When, therefore, we compare the Pilton group of South Devon with the upper part of the Old Red Sandstone, as developed in the above-mentioned localities, we have to assume that while a considerable thickness of gravels, sand, and mud chiefly mingled with an abundance of peroxide of iron, was deposited horizontally so near, no prolongation of the mass extended into North Devon, or, at least, if it did so, that the peroxide of iron was not carried so far. Taking the upper part of the Herefordshire Old Red Sandstone at about 4000 feet thick, as noticed above (p. 57), and the South Pembrokeshire section (p. 61) gives about the same depth for the same rock in that direction,* we have a considerable collective accumulation of deposits of uniform thickness and character, ranging, as it were, in face of the North Devon deposits, and at no great distance. It is indeed seen of this thickness and character as near as between the Uske Silurians and the range of the Chepstow mountain limestone, Monmouthshire.

Having a considerable thickness of sandstone, and of a kind that would agree with a partial extension of the upper part of these beds into North Devon, in the deposits comprised between the Morthoe and Foreland red sandstones, it becomes interesting to inquire how far the Pilton group may be some thick equivalent of those transition beds between

* The measured thickness of these beds, in the Herefordshire section, is 3983 feet; and, in the South Pembrokeshire section, 3798 feet.

the Old Red Sandstone and Carboniferous Limestone, so well seen in South Wales, Monmouthshire, Gloucestershire, and East Somerset. The plants noticed in the Dean Forest section (p. 58), and which are terrestrial, remind us of those discovered in the lower part of the Pilton group, near Marwood, north of Barnstaple,* and others which have been long remarked by Dr. Bright in the higher part of the Old Red Sandstone near Bristol.† In these transition beds, and in the shales, limestones, and occasional sandstones of the lower carboniferous shales, as they have been termed, above them, we may, perhaps, find a fair equivalent in geological time for the Pilton group. In the sections above given of the lower portion of the Carboniferous Limestone and of the upper part of the Old Red Sandstone at Dean Forest (p. 58), at West Angle Bay, Pembrokeshire (p. 61), at Caldy Island (p. 62), and at those of Skrinkle Haven, Pembrokeshire, of Clifton, Bristol, and of the Mendip Hills, to be noticed under the head of Carboniferous Limestone, no very exact line can be drawn, as might be expected, between these two rocks. Moreover there are often beds full of coprolites, with fish teeth and bones among them, marking a great lapse of time, without considerable local accumulations, which would agree with far more extensive and deep deposits of mud, silt, and sand, contemporaneously elsewhere.

This would agree with the view taken by Mr. Griffith in 1842,‡ who then pointed out the strong resemblance between the North Devon accumulations generally and those beds in Ireland which he has named *carboniferous slate* and *yellow sandstone*, deposits equivalent to the intermediate or transition beds between the old red sandstone and carboniferous limestone observable from Dean Forest and the Mendip Hills to Pembrokeshire, but which would appear far more developed in Southern Ireland.§

Mr. Griffith states that the carboniferous slates of the middle and northern districts of Ireland differ considerably, in lithological character,

* Geological Report, p. 50. Sedgwick and Murchison, Geological Transactions, Second Series, vol. v. p. 690. The plants of the Dean Forest section have not yet been, from accidental circumstances, properly examined, but their general aspect reminds us of those found in the Pilton group.

† Geological Transactions, First Series, vol. iv. p. 201. These plants also remind us of the plants in the Yellow Sandstone of Mr. Griffith, in Ireland.

‡ Notice respecting the Fossils of the Mountain Limestone of Ireland, as compared with those of Great Britain, and also with the Devonian System, Dublin, 1842.

§ A recent visit to the Hook Point district, Wexford, so well known for the beautiful fossils obtained for it, has shown us that the development there is much the same as in Pembrokeshire, with the exception of the yellow sandstone beds, which are thicker and more important near the Hook Point. This development becomes, however, different even so near as Clonea Castle, where the slates and accompanying limestones become thicker and are traversed by cleavage.

from those on the south, the position of which Mr. C. W. Hamilton pointed out in 1837.* Mr. Griffith shows that the southern beds are traversed by cleavage, and worked for roofing-slate, though the latter is not considered durable. With respect to the organic remains detected in the yellow sandstones and carboniferous slate, he states that, notwithstanding differences in the lithological character of these beds in the various districts, the greater number were still common to all.

With reference to the organic forms obtained from the yellow sandstone and carboniferous slate of Ireland and from the North Devon beds, Mr. Griffith observes that the investigations of Mr. McCoy, who was charged with the determination of the species, would give 35 species out of 122, or 30 per cent., as common to the yellow sandstone and the rocks of North Devon, and 65 species out of 275 species, or 24 per cent., for the species found both in the carboniferous slate and the same rocks.

This certainly is a considerable resemblance, and one which is not the less striking when we separate the Pilton, or upper group, from the lower beds and compare them with the lists of organic remains given by Mr. Griffith. Of the 80 species included in the catalogues of Professor Phillips, Professor Sedgwick, and Mr. Murchison, we find 38 in that of Mr. Griffith from the carboniferous slate of the southern district of Ireland alone, namely: — Polypiaria: (1.) *Turbinolopsis celtica*, (2.) *T. pluriradialis*, (3.) *Millipora gracilis*, (4.) *Manon cribosum*, (5.) *Glauconome bipinnata*, (6.) *Fenestella antiqua*, (7.) *F. laxa*. Crinoidea:—(8.) *Cyathocrinus macrodactylus*, (9.) *C. pinnatus*, (10.) *C. variabilis*, (11.) *Actinocrinus tenuistriatus*, (12.) *Adelocrinus hystrix*. Conchifera:—(13.) *Pecten polytrichus*, (14.) *P. transversus*, (15.) *Leptæna analoga*, (16.) *L. caparata*, (17.) *L. convoluta*, (18.) *L. membranacea*, (19.) *L. prælonga*, (20.) *L. scrabicula*, (21.) *Orthis compressa*, (22.) *O. interlineata*, (23.) *O. parellela*, (24.) *O. plicata*, (25.) *O. semicircularis*, (26.) *Spirifera calcarata*, (27.) *Sp. disjuncta*, (28.) *Sp. extensa*, (29.) *Sp. megaloba*, (30.) *Sp. microgemma*, (31.) *Sp. rudis*, (32.) *Sp. decussata*, (33.) *Terebratula oblonga*, (34.) *T. pleurodon*, (35.) *T. striatula*. Gasteropoda:—(36.) *Acroculia vetusta*, (37.) *Euomphalus serpens*. Crustacea:—(38.) *Calymene lævis*. Of these 12 species are represented as found in the yellow sandstone of the same district, namely, Nos. 6, 9, 10, 11, 15, 22, 23, 25, 26, 27, 32, and 35.

To these should be added (39.) *Spirifera mesomala* and (40.) *Sp. unguiculus*, mentioned as discovered in the carboniferous slate of the middle district of Ireland, and (41.) *Terebratula indentata*, (42.) *Nucula lineata*, and (43.) *Pleurotomaria gracilis*, from the same rock in the northern, (44.) *Bellerophon globatus* being also noticed as found in

* Journal of the Dublin Geological Society, vol. i. p. 276.

yellow sandstone of the latter. In the same list we find (45.) *Terebratula acuminata* in the lower limestones of the southern, (46.) *Pecten arenosus* of the middle, and (47.) *Bellerophon Urii* of the northern districts; (48.) *Pentremites ovalis* being mentioned as discovered in the *calp* of the northern district. Taken as a whole, therefore, with proper allowances for differences of distribution, for the varied conditions under which the animals may have lived, for the proportion of species really contained in the rocks and which may happen to be as yet found, and for skill on the part of those who have compared and determined the various organic remains noticed, there appears a very strong zoological resemblance between the Pilton group of North Devon and the lower accumulations of the carboniferous limestone of Ireland, more especially as developed in its southern district, and there would appear nothing connected with the general character of the different deposits themselves at variance with the inference that they were formed at, or nearly at, the same geological time.

These views differ but a little from that taken by Professor Sedgwick and Mr. Murchison, who refer the calcareous slates of Barnstaple to "the upper limit of the Old Red Sandstone."* Where accumulations shadow off, as it were, from the effects of one state of things to those of other conditions, it becomes no easy task, and indeed it may be doubted how far it accords with the real progress of geology to attempt fine lines of demarcation between supposed equivalents of the kind under consideration. To expect all the minor distinctions of the sand and mud banks, and sea bottoms observable in one part of a considerable area exactly to accord with those in all other parts of the same area, even though some general conditions may have been common to the whole, would agree but little with the accumulations of a similar kind now taking place, or with the minor conditions we at present see producing them.

Leaving further detail respecting the intermediate or transition beds between the old red sandstone and carboniferous limestone of South Wales, Gloucestershire and East Somerset to be hereafter noticed, we now proceed to the Petherwin beds in Cornwall, which have been referred to the same age with the Pilton group in North Devon.

The fossiliferous portions of the Petherwin accumulations consist of argillaceous slates, sometimes calcareous, intermixed with limestone, occasionally schistose, and contain numerous organic remains.† They

* On the Physical Structure of Devonshire, &c. Geological Transactions, Second Series, vol. v. p. 691.

† For more detailed accounts of these beds, see Geological Report, p. 59; Sedgwick and Murchison's Physical Structure, &c.; Geological Transactions, Second Series, vol. v. p. 668, and 695; and Phillips' Figures and Descriptions, &c. p. 195.

bear a general resemblance in mineral structure to the upper portion of the Pilton group of North Devon, and contain many of the same fossils. Professor Phillips remarks, that "on comparing 67 species of the Petherwin beds with the fossils of the groups of North Devon, we find at least 21 identical with species which occur in the Pilton group, five which are identical with forms in the Linton group, and one repeated in the Ilfracombe limestone." * Both the Petherwin and Barnstaple deposits rise from beneath a similar covering of accumulations, so that with the correspondence of organic character, noticed by Professor Sedgwick and Mr. Murchison, and viewing the subject generally, there would appear little difficulty in considering the two as the exposed ends of a mass of mud, sometimes mingled with calcareous matter, and occasionally streaked with limestone, formed anterior to the carbonaceous rocks of Devonshire, and bent up on the north and south from beneath them.†

The Petherwin beds contain a remarkable local assemblage of a polythalamaceous shell, Clymenia, of which genus, six species are noticed by Professor Phillips. Such local assemblages are very instructive, when the distribution of life, at equal geological times, is regarded with reference to such forms as may be thought characteristic. Professor Phillips very truly observes, that "as Clymeniæ are among the rarest fossils of the Irish limestone, and they are not common in Devon, and in Cornwall occur almost exclusively at South Petherwin, we are forced to ascribe to *peculiar local conditions* the unexpected plenty of these beautiful fossils here. Even within the limited range of the three quarries near Petherwin, differences appear in the distribution of organic remains. Landlake quarry, farthest to the east, and *perhaps* containing beds nearest to the base of the carbonaceous group, is richest in Cephalopoda; the middle quarry is very productive of *Spirifera disjuncta, Sp. calcarata*, &c., and I there obtained *Goniatites insignis;* while the upper or western quarry yielded us but few fossils of any description. If, on the range of nearly the same beds, the

* Professor Sedgwick and Mr. Murchison observe, on the subject of this zoological resemblance, "Those (the fossils) we have obtained from Barnstaple, Croyde Bay, Marwood, &c. (all of them places in the highest division, No. 5, of our North Devon section) certainly agree as a group with those of Petherwin, and have many species in common, as will appear by our lists. It is enough for our present purpose to quote the following:— *Spirifer attenuatus, S. bisulcatus, Orthis interlineata, Atrypa concentrica, A. decussata, A. striatula*, also a smooth and plaited species; *Leptæna caperata, L. scrabicula? Pecten s. n. Pullastra s. n.* All these shells are found both among the calcareous slates near Petherwin, and in the calcareous slates near Barnstaple; and several of the species common to both localities are extremely abundant."—Geological Transactions, Second Series, vol. v. p. 694.

† The manner in which the Barnstaple beds rise from beneath the carbonaceous rocks between Frenington Pill and Instow Hill, will be seen in the Geological Report, plate iii. section 1, and those of Petherwin from under similar accumulations, between South Petherwin and Launceston, Report, plate iv. section 2.

Tintagel slates are very different in aspect and less rich in fossils. Their lamination is parallel to the plane of deposition, and the large Spiriferæ which occur in these laminæ, are seen nowhere else of such gigantic dimensions." *

The Petherwin beds, though there is an overlap of the carbonaceous rocks above them in the direction of Tintagel, are in part exposed there, so that taken as a group, the case of a local abundance of marine animals in one place, and their scarcity in another and not far distant situation, still remains well marked.

The following are the organic remains noticed by Professor Phillips at Petherwin:—Polypiaria: (1.) *Turbinolopsis celtica*, (2.) *Amplexus tortuosus*, (3.) *Cyathophyllum cæspitosum*, (4.) *Fenestella laxa*, (5.) *F. antiqua*. Crinoidea:—(6.) *Cyathrocrinus ? variabilis*, (7.) *Cy ? ellipticus*. Conchifera:—(8.) *Sanguinolaria sulcata*, (9.) *Pullastra antiqua*, (10.) *Cypricardia semisulcata*, (11.) *Cyp. impressa*, (12.) *Cyp. deltoidea*, (13.) *Modiola amygdalina*, (14.) *Pecten granulosus*, (15.) *P. transversus*, (16.) *P. alternatus*, (17.) *P. arachnoides*, (18.) *Pterinea ventricosa*, (19.) *Avicula subradiata*, (20.) *A. exarata*, (21.) *Leptæna caperata*, (22.) *L. laxispina*, (23.) *L. fragaria*, (24.) *L. membranacea*, (25.) *Orthis interlineata*, (26.) *O. parallela*, (27.) *Spirifera protensa*, (28.) *Sp. unguiculus*, (29.) *Sp. lineata*, (30.) *Sp. decussata*, (31.) *Sp. calcarata*, (32.) *Sp. disjuncta*, (33.) *Sp. gigantea*, (34.) *Sp. grandæva*, (35.) *Atrypa desquamata*, (36.) *Terebratula pleurodon*, (37.) *T. subdentata*. Gasteropoda:—(38.) *Euomphalus serpens*, (39.) *Natica nexicosta*, (40.) *Pleurotomaria cancellata*, (41.) *Pl. antitorquata*, (42.) *Pl. aspera*, (43.) *Loxonema sinuosa*, (44.) *Lox. nexilis*, (45.) *Lox. tumida*, (46.) *Murchisonia angulata*. Cephalopoda:—(47.) *Bellerophon trilobatus*, (48.) *B. hiulcus*, (49.) *Orthoceras cinctum*, (50.) *Or. laterale*, (51.) *Or. Ludense*, (52.) *Or. ibex*, (53.) *Or. striatulum*, (54.) *Cyrtoceras rusticum*, (55.) *Nautilus megasiphe*, (56.) *Goniatites insignis*, (57.) *G. linearis*, (58.) *G. biferus*, (59.) *Clymenia lævigata*, (60.) *Cly. striata*, (61.) *Cly. linearis*, (62.) *Cly. fasciata*, (63.) *Cly. sagittalis*, (64.) *Cly. plurisepta*, (65.) *Cly. valida*. Crustacea:—(66.) *Calymene granulata*. Of these, Nos. 1, 3, 10, 11, 43, 47, 51, and 52 (8 species), are noticed as also discovered in Silurian rocks, and Nos. 2, 4, 22, 29, 36, 45, 46, and 48 (8 species), in the carboniferous limestone, one, No. 8, being mentioned doubtfully as found in the former. To this list should be added from that of Professor Sedgwick and Mr. Murchison, (67.) *Spirifera extensa*, (68.) *Terebratula hispida*, (69.) *T. indentata*, (70.) *T. triangularis*, (71.) *T. striatula*, and (72.) *T. fallax*. Of the five corals mentioned in these lists, two species are stated as found in the Silurian rocks, two species in the carboniferous limestone, and one as Devonian.

* Figures and Descriptions, &c., p. 196.

By consulting the lists of Mr. Griffith,* we find that of the 72 species enumerated by Professor Phillips, Professor Sedgwick, and Mr. Murchison, 36 species are stated as also discovered in the carboniferous limestone of Ireland, chiefly in the lower parts of that series as developed in its southern and middle districts. These 36 species consist of Corals, four species, Nos. 1, 2, 4, and 5; Crinoids, two species, Nos. 6 and 7; Conchifers, 25 species, Nos. 8, 12, 14, 15, 17, 21, 22, 23, 24, 25, 26, 27, 28, 29, 31, 32, 33, 34, 35, 36, 67, 69, 70, 71, and 72; Gasteropods, four species, Nos. 38, 45, 48, and 49; Crustaceans, one species, No. 66. So that, deducting the seven species of Clymenia, as very local, the proportion of carboniferous species to the whole of the Petherwin fossils enumerated would be, including No. 46, not noticed in Mr. Griffith's list as found in the Irish carboniferous limestone, as 37 to 65, while the Silurian species would be only as 7 to 65; *Turbinolopsis celtica*, stated to be found in the Silurian rocks of Ireland, Professor Phillips now considering to have been from the carboniferous series of that country.

We have now to regard the Petherwin group under another aspect. In North Devon, as well in the Pilton group as in those beneath, we observe no trace of igneous products which may be considered contemporaneous with the mud, silt, gravel, and limestone there deposited. In South Devon and Cornwall it is widely different in many localities, and we there discover fused trap rocks of various kinds, intermingled with trappean ash, occurring in a manner to show their contemporaneous association with the detrital accumulations of the time, and frequently pointing to eruptions either sub-aerial or beneath shallow water in different parts of the district. The lines of these igneous products, particularly those of trappean ash, are highly useful in tracing the continuity of many deposits, otherwise difficult to be followed.

In the range of beds extending from Petherwin and Lawannick, by Alternan, St. Clether, and Davidstow, to Forrabury, Bossiney, Trevenna and Tintagel, there are many of these rocks, and we are enabled, greatly by their assistance, to see that the same mass of accumulations is continued by Lanteglos, St. Tudy, and St. Mabyn, to Egloshale and Wade Bridge in one direction, and from Lanteglos by Endellyon to Padstow, Pentire Point, and Trevose Head in another, a sort of trough or depression being formed from Lanteglos south-west towards St. Kew and St. Michael. The ash is in great abundance between Lawannick and Tintagel, and not unfrequently contains much calcareous matter, showing that in the same seas into which this ash fell and was brought to rest, bicarbonate of lime was held in solution, from which calcareous matter was thrown down and intermingled with the ash beneath. The ash near Grylls on the south of Lesnewth is so impregnated with calcareous

* Notice respecting the Fossils of the Mountain Limestone of Ireland, &c.

matter that a fruitless attempt was once made to burn it into lime. While some of these ash beds assume, from consolidation, the character of fused trap, as was mentioned in the case of similar accumulations near Builth (p. 33), others are clearly sections of fused rock, intermingled with the ash, and in such a manner that with the consolidation of the latter, and the melting of it in contact with the greenstone or other trappean rock in fusion, it is very difficult to see where one variety of igneous products ends and the other commences. Very large-grained greenstone, apparently marking slow and long-continued cooling, occurs in this manner associated with schistose ash beds near Davidstow.

The passage of the ash beds into slates is often most gradual, pointing to the termination or commencement of a mingling of the mud with volcanic ash of the time at the sea bottom. Of this a good example may be observed in the cliffs near Trevelga.* Some of the trappean rocks are vesicular, the vesicles filled by carbonate of lime, which, when the rock has been long exposed to atmospheric influences, is removed, and the trap retains its original vesicular character; so that in this case we have the filling of the vesicles from the infiltration of water charged with calcareous matter, and its subsequent solution and removal by water containing the needful carbonic acid. Some of these vesicular rocks closely correspond with pumice when the carbonate of lime has been removed by natural or artificial means. As might be expected, the fused trappean rocks are here and there seen to have risen through cracks and rents in older deposits, and to have caught portions of them in their upward course. Examples of this kind are well seen at Porthqueen, and at Kellan Head we found fragments of slate, which have been thus broken off, contained in the igneous mass, such fragments being converted either into a porcellanic substance or otherwise altered.

The continuation of the Petherwin group by Tintagel to Padstow, though calcareous matter is frequently present, has not been found very fertile in organic remains. They have been discovered on the coast at Permizen Bay,† westward from Padstow, and more abundantly in the slates associated with calcareous beds at Dinas Cove, south of the latter place. A coral, *Turbinolopsis celtica*, found also at Petherwin, occurs abundantly at Dinas Cove, and indeed seems to constitute the chief determinable fossil of the locality. The coast and interior sections show that these beds rise towards an anticlinal line ranging along St. Breock's

* The long celebrated Delabole slate quarries belong to this series of beds.—Report, pp. 58 and 88. To that work we must also refer for a more detailed account of the trappean and detrital rocks mentioned above.

† The fossiliferous character of the Permizen rocks had been noticed by Professor Sedgwick as early as 1828.

Downs, on the south side of which, at St. Wenn and St. Columb, they again come in, and are thence continued to New Quay,* where fish remains, with crinoidal columns and *Turbinolopsis celtica*, are found in the calcareous slates. The anticlinal axis of St. Breock's Down, the beds of which are seen to be much contorted in a minor manner at High Cove, near Trenance Point,† are chiefly composed of arenaceous rocks, sometimes micaceous; many beds approaching quartz rock.

In endeavouring to connect the Pilton group of North Devon with the Petherwin group and its continuation to Lower St. Columb Porth and New Quay, these sandstones rising from beneath the latter at St. Breock's Downs would remind us of the position of the Morthoe beds. Red and variegated slates can be traced from Tregoss Moors to a fine section of them in Watergate Bay, and the calcareoaus nd fossiliferous rocks of Porth Island, Lower St. Columb Porth, referred above to the Petherwin group, are seén to rest upon them. The section from the Camel to Pentire Point near Padstow‡ also shows the fossiliferous beds, opposite Cant Hill and near Bodillick, occurring in a position somewhat similar; the argillaceous slates, chiefly red and claret-coloured, which are found northward of the limestone of Rock, leading to this view. We have hère beds, therefore, containing much peroxide of iron, in a geological position not different from the Morthoe red and variegated strata.

On the westward of New Quay there is much uncertainty as to the continuation of the fossiliferous rocks. The slates there containing limestone beds, dip southward from the variegated beds in Watergate Bay; and near Ligger Point, north of Piran Bay, the same dip may be observed. Unfortunately sands cover the bottom of this bay, and conceal a section which would otherwise be so valuable.

Returning to the vicinity of Petherwin, and endeavouring to follow its fossiliferous rocks eastward, we soon experience great difficulties, arising in no slight degree from the admixture of the igneous products with the sediments of the time, and the apparent passage of the group in a complicated manner amid volcanic eruptions into the superincumbent carbonaceous rocks. It would appear as if trappean ash had been thrown out abundantly from some vent or vents between Petherwin and Tavistock, this ash being accumulated in great thickness about Milton Abbot and other adjacent places. Volcanos seem to have ejected molten matter and ashes during the formation of the Petherwin rocks and of those which immediately followed, so that their products became equally mingled with both accumulations.

The slaty ash beds are occasionally calcareous, and are intermingled

* Geological Report, plate ii. fig. 3. † Ib., p. 90, fig. 10.

‡ Ib., plate ii. fig. 3. Near New Quay and Crantock, the slates in which the calcareous beds occur are much cut up by intrusive trap. See Report, p. 87, figs. 8 and 9.

with calcareous slate and nodules of limestone at Longford, between Kilworthy and Tavistock,* and in the valley of the Inny, between Trekellern and Trecarrell Bridge, fused trap and ash are intermingled with argillaceous slate and a small quantity of limestone. Calcareous matter is so abundant among the trappean ash of this locality, that by selecting the more calcareous portions it is burnt for lime, great care being taken to prevent any slag from forming in the kilns.

An excellent example of pumice filled with carbonate of lime occurs near Trecarrell Bridge. Although the trappean rocks of Devon and Cornwall often exhibit a vesicular character, we know of no locality where it can be better seen, or where the vesicles will be observed to be so numerous and the partings between them so thin.†

At Tavistock, also, near the Abbey, calcareous matter is mixed with the volcanic products. In the ash it may have been contemporaneously deposited, but in the vesicular trap it was necessarily introduced after the solidification of the igneous rock, and apparently from adjacent deposits, in both cases pointing to much disseminated carbonate of lime amid the accumulations of the period, and yet organic remains have not hitherto been detected in this assemblage of rocks; a fact, as they are abundantly discovered so near as Petherwin, which would seem to point to some condition of the sea unfavourable to the existence of marine life in it. At the present day molluscs are found on and in volcanic ash; we have seen they were so at the epoch of the Silurian deposits (p. 31), and we shall have to notice a similar case among the rocks of South Devon, so that as the occurrence of the ash alone, when not showered upon or borne into the sea too rapidly, does not appear a sufficient cause in itself for the absence of marine animals, the waters in which the deposits were effected may have been locally impregnated with matter ill suited to animal life.

On the east of Tavistock the granite of Dartmoor has been thrust up, cutting off many rocks in that direction, while some have been forced northward, and bent round towards Chudleigh. This displacement over so considerable an area, with the actual separation of some accumulations for many miles in distance, it may readily be supposed, greatly embarrasses attempts to trace the Petherwin group on the east of Dartmoor, between the granite of the one side, and the covering up of new red sandstone, or poicilitic rocks on the other, more particularly as we have seen that though so fossiliferous at Petherwin, organic remains become exceedingly scarce on the west towards Tintagel, Padstow, and New Quay, and on the east towards Tavistock. From the displacement, moreover, produced by the upthrust of such a mass of granite as that of Dartmoor, we may have contortions and flexures on

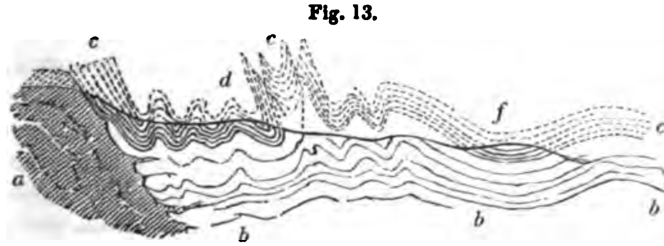
* Geological Report, plate iv. fig. 4.

† Geological Report, &c., p. 61.

its flanks, productive of very deceptive sections, deceptive at least as regards deductions from such sections alone, with respect to the relative ages of the beds against which such great lateral pressure has been exerted. Of this character may the sections be, extending from Chudleigh to Holme, and its neighbourhood, in which the carbonaceous rocks, or "culm measures," of central Devon have the appearance of dipping beneath the argillaceous slates, limestones, and trappean rocks of Ashburton and Buckfastleigh.*

As we can trace the group of accumulations, of which the Ashburton and Buckfastleigh beds constitute a part, round the southern part of Dartmoor, to and beyond Plymouth, if this appearance of the carbonaceous rocks dipping beneath them were not fallacious, we ought to find such rocks in their places to the northward of Plymouth, and in the fine natural section afforded by the Tamar. As we do not there discover them, and do find similar beds, containing the same fossil plants, above the South Devon slates and limestones (of which the Ashburton and Buckfastleigh beds form a part), between East Ogwell and Abbots Kerswell,† some complication of appearances, produced by reversed dip, may be the cause of the apparent difficulty. If we assume this explanation, great curvature of beds would seem needed, and in a form to which subsequent denudation would give the fallacious appearance of a constant dip in one direction for a considerable distance. We know that such fallacious appearances are produced elsewhere from this cause, and thus might assume that a system of contortion and subsequent denudation, of the general character sketched beneath (fig. 13), would

Fig. 13.



a, protruded granite; *b*, *b*, *b*, lower slate and limestone rocks; *c*, *c*, *c*, carbonaceous and upper rocks which at *d* have the deceptive appearance of dipping beneath the really lower rocks, *b*, *b*, *b*, while at *f* they are seen clearly to rest upon them.

cause a somewhat similar deceptive appearance, the sketch exhibiting this view in a general manner, and without endeavouring actually to represent the country, or its restoration to its supposed condition anterior to denudation.‡

* Geological Report, &c. plate iv. sections 5 and 6.

† Geological Report, &c. plate iv. fig. 5.

‡ The extent and supposed magnitude of the contortions, and the subsequent removal

Taking this view, it would also appear necessary to consider that there had been an overlap of carbonaceous rocks between East Ogwell and Abbots Kerswell, where Mr. Austen notices their unconformable position upon the lower rocks, which have been abraded and furnished materials (blocks mostly angular, or slightly waterworn, of the subjacent limestone) for their lower beds;* a fact which would still further complicate the subject.

Failing to find sections which would join the Petherwin group with the South Devon limestones and slates by means of a well-established connexion with the carbonaceous rocks above, we turn to the country between Petherwin and Plymouth for the purpose, particularly as the Tamar, cutting through the various rocks, as a whole, at right angles to their direction or strike, appears to offer great facilities for the purpose. Whatever artificial sections may hereafter effect, those which are exposed naturally have not hitherto afforded this information in the manner that could be desired. By means of a thin limestone bed near Trewarlet (north from Lezant), we may infer that the Petherwin rocks, which dip northward beneath the carbonaceous rocks towards Launceston, arch over with a reversed dip towards the south. When, however, the limestone ends, and we have only slates for guides, without more solid beds to lead us, the difficulty of finding how far cleavage may interfere with the original lamination from deposit becomes considerable, and we may readily have the argillaceous beds of the Petherwin group, without limestones or sandstones, contorted out of the section without being aware of the fact.

If we avoid the granite of Kit Hill, which has thrust up and altered the beds in contact with it, as much as we can conveniently do, and take, as elsewhere stated,† the mass of the slate country through Lezant, South Sydenham, Morwell Down, and Buckland Monachorum, to a line from St. Ive (near Liskeard), through St. Mellion, Beer Ferrers, to Bickley, and trust to the planes of general lamination alone, the whole when not immediately near granites, elvans, or greenstones, would be considered to dip to the south. In the vicinity of Tavistock, the laminæ of the slate dip in so many directions, that it is difficult to decide which may prevail. Near Wheal Franco Copper Mine they are nearly horizontal.

Under these circumstances, and considering that we possess geological evidence of the granite of Dartmoor on the east, and of that between Liskeard and Camelford on the west, having thrust aside and upraised

of their upper portions by denudation, would be far less than many cases of both observable in Wales a notice of which will appear in a memoir by Mr. Ramsay.

* On the Geology of the South East of Devonshire, Geological Transactions, Second Series, vol. vi. p. 458, fig. 9.

† Geological Report, &c., p. 62.

the various accumulations, including prior igneous products, which came in the way, it may be safest for the present to infer that the beds between these masses (apparently connected beneath, as shown by the granite of Kit Hill, and the same range of high ground), have been upraised also, so that an anticlinal axis has been formed. This would throw the Petherwin group to the northward, ranging round by Tintagel, Padstow, Lower St. Columb Porth, and New Quay westward, while it would be cut off eastward by the protruded granite of Dartmoor.*

Finding the South Devon limestones, slates, and sandstones thus not satisfactorily joined with the Petherwin group by means of well-connected and continuous accumulations of detrital and calcareous matter, which could, without doubt, be referred to the same geological time; we necessarily turn to such evidence as organic remains may afford us as to their position in the geological series, due regard being paid to their lithological character. We have seen (p. 65) that Mr. Lonsdale concluded from zoological evidence, that the South Devon limestones were of the age of the old red sandstone of Herefordshire, and that Professor Sedgwick and Mr. Murchison adopted that conclusion. Whatever difficulty may have been experienced with respect to the relative position of the carbonaceous rocks and the slates and limestones of Ashburton and Buckfastleigh, none exists with reference to the superposition of the rocks towards Torbay and Dartmouth.†

Many years since, it was shown that the Torbay and Babbacombe limestones rested upon a red sandstone, and from the few species of fossils (21) then found, it was supposed (the organic remains in the deposits, now known as Silurian, being then little understood) that the limestone should be referred to the carboniferous limestone; the previously known species (considered to be four) having been found in that rock, and the remainder being new.‡

Mr. Austen, during his residence at Ogwell House, subsequently devoted much attention to the geological structure and organic remains of his neighbourhood, and formed extensive collections of those fossils, which have since been so valuable in inquiries connected with the rela-

* Professor Phillips, when noticing the difficulty of connecting the Petherwin with the Plymouth group of deposits, observes, "The principal part of this difficulty arises from the nature of the country intervening between the groups; for not only does it present rocks not common to either, but these are found so variously posited, and so much disturbed by the crossing of mineral veins and trap courses, that a more embarassing line of country can scarcely be imagined."—Figures and Descriptions, &c. p. 197.

† Geological Report, plate iv. figs. 5 and 6; Sedgwick and Murchison, Geological Transactions, Second Series, vol. v. plate li. figs. 6 and 8; and Austen, Geological Transactions, Second Series, vol. vi. plate xlii. figs. 1, 2, 3, 4 and 6.

‡ De la Beche, Geological Transactions, Second Series, vol. iii. p. 164. The limestone being considered carboniferous, the red sandstones beneath it lithologically resembling those of the Old Red Sandstone of Somersetshire, &c., were referred to that rock.

tive age of the rocks of this district, affording, as he did, their free use to all who desired it.* In a memoir read before the Geological Society in 1836, Mr. Austen stated that these limestones and others in the vicinity contained an abundance of organic remains,† and in 1837 he further noticed them in a memoir on the south-east of Devonshire.‡ It was after the reading of this communication, and partly from an examination of Mr. Austen's specimens, that Mr. Lonsdale formed his opinion respecting the geological age of the South Devon limestones, and referred them to that of the old red sandstone.§ Subsequently, in 1839, Mr. Austen read another memoir on the structure of South Devon.‖

So thickly congregated together are the organic remains in parts of the limestones of Babbacombe, Barton, and Newton, that from the Newton Quarry alone Mr. Austen enumerates the following:¶—

(1.) *Brontes flabellifer*, (2.) *Calymene Latreillii*, (3.) *C. Sternbergii*, (4.) *Orthoceras cinctum*, (5.) *O. ellipsoideum*, (6.) *O. pyriforme*, (7.) *O. tubicinella*, (8.) *O. ventricosum*, (9.) *Cyrtoceras armatum*, (10.) *C. fimbriatum*, (11.) *C. marginale*, (12.) *C. nautiloideum*, (13.) *C. nodosum*, (14.) *C. obliquatum*, (15.) *C. ornatum*, (16.) *C. quindecimale*, (17.) *C. reticulatum*, (18.) *C. rusticum*, (19.) *C. tridecimale*, (20.) *Nautilus germanus*, (21.) *Goniatites excavatus*, (22.) *G. globatus*, (23.) *G. serpentinus*, (24.) *G. transitorius*, (25.) *Bellerophon hiulcus*, (26.) *B. striatus*, (27.) *B. Wenlockensis*, (28.) *B. Woodwardii*, (29.) *Buccinum acutum*, (30.) *B. arculatum*, (31.) *B. imbricatum*, 32.) *B. spinosum*, (33.) *Murex? harpula*, (34.) *Pleurotomaria antitorquata*, (35.) *P. aspera*, (36.) *P. cancellata*, (37.) *P. impendens*, (38.) *P. monilifera*, (39.) *Schizostoma tricinta*, (40.) *Macrocheilus elongatus*, (41.) *Terebra Hennahii*, (42.) *T. nexilis*, (43.) *Turritella abbreviata*, (44,) *Loxonema reticulata*, (45.) *L. lineata*, (46.) *Turbo textatus*, (47.) *Euomphalus annulatus*, (48.) *E. circularis*, (49.) *E. radiatus*, (50.) *E. serpens*, (51.) *Nerita spirata*, (52.) *Pileopsis vetusta*, (53.) *Pleurorhynchus aliformis*, (54.) *Pl. minax*, (55.) *Modiola scalaris*, (56.) *Mytilus Damnoniensis*, (57.) *Megalodon carinatum*, (58.) *M. cucullatum*, (59.) *Pterinea*, (60.) *Avicula texturata*, (61.) *Av? reticulata*, (62.) *Pecten plicatus*, (63.) *Leptæna fragaria*, (64.) *L. nodulosa*, (65.) *L. rugosa*, (66.) *Orthis arachnoidea?* (67.) *O. arcuata*, (68.) *O. crenistria*, (69.) *O. granulosa*, (70.) *O. Hardrensis*, (71.) *O. interstrialis*, (72.) *O. resupinata*, (73.) *O. lens*, (74.) *Delthyris (Spirifera) cuspidata*, (75.) *D. distans*, (76.) *D. hirundo*, (77.) *D. microgemma*, (78.) *D. nuda*, (79.) *D. heteroclita*, (80.) *B. oblata*, (81.) *D. plebeia*, (82.) *D. phalæna*, (83.) *D. simplex*, (84.) *D. subconica*, (85.) *D. speciosa*, (86.) *D. unguicula*, (87.) *Strygocephalus? Burtini*, (88.) *Terebratula acuminata*, (89.) *T. anisodonta*, (90.) *T. aspera*, (91.) *T. bifera* (92.) *T. cassidea*. (93.) *T. comta*, (94.) *T. (Atrypa) crenulata*, (95.) *T. (At.) cuboides*, (96.) *T. (At.) desquamata*, (97.) *T. ferita*, (98.) *T. flexistria*, (99.) *T.*

* Among others, the Geological Survey of Great Britain has had to acknowledge the liberal use of specimens for Professor Phillips' Figures and Descriptions of the Palæozoic Fossils of Cornwall, Devon and West Somerset.

† Proceedings of the Geological Society, vol. ii. p. 414. ‡ Ibid, vol. ii. p. 584.

§ Geological Transactions, Second Series, vol. v. p. 724.

‖ The substance of these memoirs and of an account of a Raised Beach at Hope's Nose, read Nov. 1834, and of another memoir on the Bone Caves of Devonshire, read March 1840, was published in the Geological Transactions, Second Series, vol. vi., as one memoir on the Geology of the South East of Devonshire, accompanied by a map, a reduction of that with which Mr. Austen furnished the Geological Survey, and which was subsequently published as part of the Geological Survey Map of Devonshire. See Geological Report, &c., p. 69.

¶ Geological Transactions, Second Series, vol. vi. p. 466.

(*At.*) *galeata*, (100.) *T. hastata*, (101.) *T. juvenis*, (102.) *T. Mantiæ*, (103.) *T. prisca* (104.) *T. proboscidialis*, (105.) *T. pleurodon*, (106.) *T. pugnus*, (107.) *T. reniformis*, (108.) *T. rhomboidea.* (109.) *T. sacculus*, (110.) *T. Wilsoni*, (111.) *Cyathocrinites geometricus*, (112.) *Cy ? nodulosus*, (113.) *Actinocrinites triacondactylus*, (114.) *Platycrinites interscapularis*, (115.) *Pl. pentangularis*, (116.) *Pl. tuberculatus*, (117.) *Sphæronites tesselatus*, (118.) *Stromatopora concentrica*, (119.) *St. polymorpha*, (120.) *Fenestella abnormis*, (121.) *F. antiqua*, (122.) *Retepora infundibulum*, (123.) *Ret. prisca*, (124.) *Lithodendron cæspitosum*, (125.) *Amplexus tortuosus*, (126.) *Cyathophyllum turbinatum*, (127.) *Cystiphyllum Damnoniense*, (128.) *Cys. vesiculosum*, (129.) *Strombodes vermicularis*, (130.) *Astræa ananas*, (131.) *As. helianthoides*, (132.) *As. Hennahii*, (133.) *As. pentagona*, (134.) *Porites pyriformis*, (135.) *Coscinopora placenta*, (136.) *Favosites fibrosa*, (137.) *Fav. Gothlandica* (138.) *Fav. polymorpha*, (139.) *Fav. spongites.*

Such an abundance of organic forms, considered specifically distinct, from a single quarry, shows how rich this limestone must be in the remains of marine animals, crustaceans, molluscs, crinoids, and corals, existing at the time of its formation, and affords excellent means of comparison with the animal forms detected in rocks, the place of which in the geological series may be well established, more particularly in localities not far distant.

From the South Devon limestones occurring in patches amid slates and sandstones, and from having been, with their associated slates, sandstones, and trappean rocks, subjected to great pressure, which has forced them into various positions, sometimes curved and bent round a dome-like protrusion, while they are contorted,* and even thrown into high angles in many localities, and from being also occasionally cut off by denudation from each other, much care is required in assigning them their equivalent, or relative superposition, as the case may be, in the general series of which they constitute parts, more particularly as their zoological character is considered materially to correspond. In many localities, also, the overlap of the new red sandstone series conceals important sections.

In the irregularly formed and dome-like protrusion which throws the limestone around it from Torquay, by Tor Moham, St. Mary Church, Anstis Cove, Hope's Nose, the Thatcher Rock, and the Shag Rock,† we find a base of sandstones frequently red. Red sandstones and slates are common in the range of country extending from Cockington, southwards of Berry Pomeroy, towards the Dart, and red rocks dip beneath the Berry Head, Brixham, and Galpton mass of limestone, southward of Paignton. In the direction of Langcombe, east from Totnes, red sandstone is abundant, and in it occur limestone bands, the most considerable of which does not exceed a mile in length. The patch of limestone extending from the Dart to Higher Yalberton, appears

* For sketches of some of these contortions see plates accompanying a paper on the Geology of Tor and Babbacombe Bays, Geological Transactions, Second Series, vol. iii.

† This range of limestone is well shown in Mr. Austen's map, Geological Transactions, Second Series, vol. vi. plate xli.

to rest upon red slates and sandstones. Thus part, at least, of the limestones of this portion of Devonshire, rests upon, or is intermingled with, sandstones or slates, coloured red from a sufficient abundance of peroxide of iron.

Though calcareous matter is more scarce in the country between Plymouth and the district above noticed, including that of Chudleigh, Ashburton, Ogwell, and Totnes, there is no difficulty in seeing that the limestones in both are geologically connected. In this intermediate country we find beds, highly coloured by peroxide of iron, intermingled with the sandstones or slates, as the case may be; and at Plymouth the mass of limestone is seen to be covered by a considerable thickness of red sandstones and slates, the former often extremely hard.* We have evidence, therefore, that these limestone deposits are associated in such a manner with red sandstones and slates, among other rocks, that they may be observed in different localities either resting upon, included among, or covered by them.

With the sandstones and slates of other colours, also associated with these limestones, we have trappean rocks of a character which, though often showing intrusion among some parts of the general accumulation of beds, points to much local and contemporaneous volcanic action as a whole. Mr. Austen long since discovered organic remains in the volcanic ash, associated with more solid trappean rocks, upon which, as a floor, part of the Ogwell limestones were deposited,† and much ash and vesicular igneous rocks are intermingled with the great collection of beds of which the South Devon limestones constitute a part. A mass of ash and vesicular trap is observed to the eastward of the Yalberton limestone, and there is a small band of limestone apparently included

* Professor Phillips gives the following section of the Plymouth rocks in ascending order:—

1. Purple slaty rocks, highy laminated.
2. Plymouth limestones. Some beds mere coral masses. In upper part, red shales, yellow ochry beds, and purple masses of oxide of iron form a parting in the limestone.
3. Laminated schistose beds, irregular beds of trappean rock, with irregular and nodular admixtures of limestone.
4. Blue and gray schistose beds, with nodular limestone. Fossiliferous.
5. *a.* Carbonaceous and gritty beds. *b.* Argillaceous contorted schists. *c.* Calcareous laminæ.—Fossiliferous. *d.* Schists. *e.* Schists and thin grits. *f.* Laminated brown and red grits. *g.* Schists. *h.* Layers of nodular limestones, with Crinoidea.
6. *a.* Red grits, hard and coarse. *b.* Purple schists and fossils in bands. *c.* Red grits, with gray alternations, often ripple-marked on the surface; much resemble the beds of Martinhoe, North Devon.
7. Blue and gray shales, with thin calcareous bands.—Bovey Sand Bay.

Figures and Descriptions of the Palæozoic Fossils, &c., p. 201.

† Report, &c. p. 70. Mr. Austen, in his Memoir on the Geology of the South-East of Devonshire, states these beds to swarm with organic remains, chiefly Fenestellæ, columnar joints of Crinoidea, and shells of Brachiopoda.—Geol. Trans., Second Series, vol. vi. p. 471.

in it. A conglomerate containing quartz pebbles as large as a nut is also associated with this mass of vesicular trap and ash, pointing to the contemporaneous mixture of volcanic and aqueous products.

Mr. Austen directs attention to a very illustrative example of the contemporaneous intermixture of volcanic products with the rock formations of the time at Denbury, where the partings between the beds of limestone, composed chiefly of branching corals, "are of volcanic sand, which is easily removed, and we then obtain an upper surface studded with projecting stars and branches, as perfect as when the sand was thrown upon them and suspended the labours of the polyps."*

Many other cases of vesicular trap and ash occur, which, with the intrusive igneous rocks of more solid character, point to considerable volcanic action in this district, one more or less common to the accumulations of contemporaneous date, extending from it to Plymouth, Saltash, and St. Germans.†

Between the Tamar and the Teign, near Newton Bushel, including the Torbay district, we have a mass of accumulations which, though not marked by continuous bands of similar detrital or calcareous matter, still presents a certain general character as a whole. Sand and mud banks appear to have been contemporaneously mixed, and the one kind graduated into the other, so that now we find them in a consolidated state, as sandstones graduating into slates. Among these banks were coral reefs and accumulations of shells, sometimes more prevalent in

* Austen on the Geology of the South-East of Devonshire, Geol. Transactions, Second Series, vol. vi., p. 465.

† For greater detail of these rocks, and of the associated accumulations, see Report, &c., p. 62–76; Sedgwick and Murchison on the Physical Structure of Devonshire, &c. Geol. Trans., Second Series, vol. v. p. 649–662. These authors divide the South Devon rocks, in ascending order, into four groups:—1. The slate rocks bordering upon Dartmoor, many parts of which are indurated and altered in structure by the action of the granite. 2. A great zone of slates, more or less calcareous, with subordinate beds of limestone, the lower portion containing the Ashburton bands, the upper containing the great Plymouth and Tor Bay limestone. The upper portion also contains occasional beds of red slate and sandstone, which sometimes appear under the limestone, and sometimes seem to take its place along the lines of strike. 3. A great arenaceous group, containing many beds of red and variegated sandstone. 4. A group with many courses of soft, glossy slate, sometimes indurated, and used for roofing-slate, alternating with coarse quartzose bands, without any subordinate beds of limestone, and apparently without fossils. These four groups complete the ascending series, and are, together, of an enormous thickness.—Austen, Geology of the South-East of Devonshire, Geol. Trans., Second Series, vol. vi. p. 462–473. The following is Mr. Austen's view, in the descending order, of the relative superposition of the rocks noticed in his Memoir:—1. Coral limestone of Newton, Barton, Torquay. 2. Red sandstones and slates, extending from Paignton, Windmill Hill, near Berry Pomeroy, and across the Dart about Sharpham. 3. Limestones of Yalberton, Berry, and lower limestone of the Ogwell country. 4. Lower limestones, with contemporaneous trappean beds, ranging from Staple Hill, by Bickington, Ashburton, Buckfastleigh, and Dean Prior; separated from No. 3 by slate (with occasional lines of fine-grained fossil beds), fit for roofing-slate.

one part of the area than in another. At the same period volcanos locally existed, and threw out their ashes and their lava streams, forcing molten matter amid and into the cracks of the older deposits, which must have been often previously consolidated, as fragments of them are caught up, or the cracks in them formed, in a manner that justifies the conclusion. This action being continued irregularly, we have as the result very irregular minor accumulations above each other, due in no slight degree probably to the volcanic condition of part of this area at that geological time. Occasionally there was much peroxide of iron mingled with the detrital deposits now forming red sandstones and slates. These, however, are usually not very continuous, so that there is great difficulty in tracing them for any considerable distance, though, as a whole, they constitute a marked feature amid the general accumulations of the district.

Among the deposits southwards of the general range of calcareous country above noticed, there is also much red slate and sandstone, in some measure perhaps partly replacing it.* At Black Down and Morleigh Down light-coloured beds, often micaceous, pass into quartz rock, the cementing siliceous matter having destroyed, in a great measure, the granular character of the light-coloured sand originally deposited. A condition apparently due here, as in many other instances, to the introduction of silica amid the sand, under conditions favourable for the frequent and intimate union of the unfiltrated matter with the external portions of the grains of sand, drifted together so as to form a sandbank of nearly pure quartz. Much red mud was associated with the gray southward of these sandy accumulations, mingled with a minor proportion of sand; and the Start Bay sections show us that many minor masses, which were red in that direction, were gray westward, towards Bigbury Bay, so that peroxide of iron coloured the mudbanks but partially, red mud being probably drifted to them in one place, while the common gray mud was thrown down upon them in another.

As we have elsewhere remarked,† those who have seen coral reefs cannot but be struck with the resemblance many of the South Devon limestones present to such polyp-formed masses of calcareous matter. Their sudden termination and the presence of slates in their line of strike remind us of coral reefs against which mud has accumulated, the mud finally destroying the polyps, and enclosing the whole reef, with its associated molluscs, in a mass of clay or mud, now converted into hard

* See Report, &c., plate ii. fig. 1, where several miles of country south of the limestones of Dunwell are shown to be composed of sandstones and argillaceous slates, among which red beds are frequent. The same fact is shown by Professor Sedgwick and Mr. Murchison, Geol. Trans., Second Series, vol. v. plate li. figs. 5 and 6.

† Report, &c., p. 147.

slate. In this manner we can readily account for the disappearance of the many animal remains detected in the limestones and not found in the slates prolonged in the same line of strike, the muddy or arenaceous state, as the case might be, of the detritus drifted against the coral reefs not having been suited to the creatures that lived amid the corals.* In like manner we can understand the presence of the same creatures (the polyps having been successful in establishing their reefs), in the various patches of limestone isolated amid the sandstones and slates, even though not exactly in the same line of deposit, the young of the polyps fixing themselves favourably from time to time, and the young of the animals usually associated with them, flourishing in the same localities with them. And we should recollect that numbers of these isolated patches may be concealed from our observation, since we only see in section, and upturned, a minor portion of the sea-bottoms accumulated above one another at that time.

Mr. Austen, who has carefully studied the South Devon limestones with reference to their origin, observes, that very little personal examination would soon satisfy any one that the principal limestone masses have resulted from the labours of polyps, or existed as coral reefs; and remarks, that in the parish of East Ogwell each bed is entirely composed of branching corals in the position in which they grew. He observes, that, "among existing zoophytes the lamellated and cellulated orders seem to be the principal agents in constructing reefs, and their analogues mainly compose the Devonshire limestone."† The same geologist also remarks that there are certain local associations of generic and even specific forms observable. "Thus the limestone of Newton abounds in *Cyathophyllæ* and *Coscinoporæ;* that near Chercombe Bridge seems to have been almost exclusively constructed of *Favosites polymorpha*, and *Favosites spongites;* whilst about Denbury, *Favosites alveolaris* and other allied species are most abundant."‡

Adverting to the wide difference observable in the suite of organic remains obtained from the slates and from the coral limestones, though in many instances contemporaneous, as the natural result of the different habits of marine animals, Mr. Austen remarks, that "the Terebratulæ, which so swarmed about the reefs where they had the means of fixing themselves, that we find twenty-three species in the Newton quarry alone, are altogether wanting in the slate." The constancy of certain forms, as indicative of similar conditions, is pointed out, and *Fenestellæ*, *Turbinoliæ*, *Pleurodyctium problematicum*, &c., are instanced as ranging

* For further remarks on this subject, applicable to the district, see Report, &c., p. 147-149.

† Geology of the South-East of Devon. Geol. Trans., Second Series, vol. vi. p. 465.

‡ Ibid.

through the whole middle slate district of South Devon, and as continued into Cornwall. He also observes, that "the large *Strygocephali* of South Devon evidently covered extensive surfaces as oyster-beds do now, thick strata being entirely composed of their uninjured shells at Chudley, Chercombe Bridge, Bradley, and Plymouth.*

The labours of Mr. Lonsdale, Professor Phillips, Mr. Austen, and of Professor Sedgwick, and Mr. Murchison, not forgetting the collections made by the zeal and perseverance of Mr. Hennah, have thrown great light on the organic remains contained in the South Devon rocks, more especially in the limestones associated with them; and Professor Sedgwick and Mr. Murchison pointed out (in 1837) that there was a near resemblance in many of the fossils, especially in the corals, between the North and South Devon rocks, and inferred generally that the lower parts of the South Devon accumulations were geologically lower than the lowest members of the North Devon series.† Professor Phillips concluded from his researches that there was a much greater affinity between the Petherwin and Pilton groups and the carboniferous limestone than with the Silurian rocks, and a much greater approach of the South Devon group to the Silurian period.

At the same time he points out that the reasoning "is liable to an irremovable doubt as to the degree in which the differences depend on mere local circumstances rather than on sequence of time, which, for the sake of the illustration, is assumed to be the governing element."‡ He observes that, while in North Devon and North Cornwall the analogues of *Spirifera attenuata* and *Leptæna scrabicula* are plentiful, *Atrypa prisca* and a considerable number of corals, identical as species with those discovered in the Silurian rocks, are found in South Devon. He also remarks that, with respect to the Brachiopoda generally, South Devon presents a very positive analogy to the carboniferous limestone series, and observes, that its affinity both to the carboniferous and Silurian series may depend upon the same cause, the predominance of fossils found in limestones.§ Of the 166 species enumerated by Professor Phillips in the Plymouth or South Devon group,‖ 67 species, or about

* Geology of the South-East of Devonshire, Geol. Trans., Second Series, vol. v. p. 468. Mr. Stutchbury observes (West of England Journal, p. 47), on the subject of the distribution and mode of occurrence of recent shells in the Pacific, that he has seen "beds of *Cardium fragum* from six to eight feet thick, and more than two miles in extent, without even the broken portion of any other shell being deposited in the same stratum."

† On the Physical Structure of Devonshire, &c., Geol. Trans., Second Series, vol. v. p. 663.

‡ Figures and Descriptions of the Palæozoic Fossils, &c. p. 171.

§ Ibid., 172.

‖ Polypiaria, 28 species; Echinodermata, 9; Conchifera Plagimyona, 7,; Con. Mesomyona, 6; Con. Brachiopoda, 55; Gasteropoda, 27; Cephalopoda Monothalamacea, 4; Ceph. Polythalamacea, 21; and Crustacea, 9.—Figures, &c., p. 169.

40 per cent., are contained in the lists given by Mr. Griffith of those found in the carboniferous limestone of Ireland.* Of 24 additional species, enumerated by Mr. Lonsdale, Professor Sedgwick, and Mr. Murchison, and not included in the catalogue of Professor Phillips, 6 only are mentioned in the lists of Mr. Griffith, so that, taking the total number of species noticed in South Devon as 190, and 72 as the number observed in the Irish mountain limestones, the proportion of species common to South Devon, and the latter would be 37.9 per cent. of the South Devon fossils. There are 10 species not noticed in the carboniferous limestone of Ireland by Mr. Griffith, which are mentioned in the catalogue of Professor Phillips as discovered in the carboniferous limestone of England, and one additional in the lists of Mr. Lonsdale, Professor Sedgwick, and Mr. Murchison, so that out of the 190 species noticed in South Devon, 83, or nearly 44 per cent., are considered to have been found in the carboniferous limestone of some part of the United Kingdom. These 83 species are as follows:—

Polypiaria:—(1.) *Turbinolopsis celtica*, (2.) *Amplexus tortuosus*, (3.) *Favosites polymorpha*, (4.) *F. Gottlandica*, (5.) *F. spongites*, (6.) *F. fibiosa*, (7.) *Stromatopora polymorpha*, (8.) *St. concentrica*, (9.) *Caunopora placenta*, (10.) *Pleurodyctium problematicum*, (11.) *Millepora similis*, (12.) *Fenestella laxa*, (13.) *F. antiqua*, (14.) *Retepora prisca*, (15.) *Hemitrypa oculata*. Crinoidea:—(16.) *Platycrinus interscapularis*, (17.) *Pl. tuberculatus*, (18.) *Pl. pentangularis*, (19.) *Cyathocrinus geometricus*, (20.) *Cyathocrinus megastylus*, (21.) *Antinocrinus 30-dactylus*. Conchifera Plagymyona:—(22.) *Pleurorynchus minax*, (23.) *Pl. aliformis*. Conchifera Mesomyona:—(24.) *Pecten polytrichus*, (25.) *P. plicatus* Conchifera Brachiopoda:—(26.) *Leptæna nodulosa*, (27.) *L. rugosa*, (28.) *L. fragraria* (29.) *L. interrupta*, (30.) *Calceola sandalina*, (31.) *Orthis sordida*, (32.) *O. Hardrensis*, (33.) *O. arcuata*, (34.) *O. plicata*, (35.) *O. granulosa*, (36.) *O. crenistria*, (37.) *O. arachnoidea*, (38.) *O. resupinata*, (39.) *Spirifera microgemma*, (40.) *Sp. oblata*, (41.) *Sp. unguiculus*, (42.) *Sp. plebeia*, (43.) *Sp. phalæna*, (44.) *Sp. simplex*, (45.) *Sp. cuspidata*, (46.) *Sp. distans*, (47.) *Sp. disjuncta*, (48.) *Sp. costata*, (49.) *Sp. nuda*, (50.) *Sp. rotundata*, (51.) *Sp. inornata*, (52.) *Sp. pulchella*, (53.) *Strigocephalus Burtini*, (54.) *Atrypa aspera*, (55.) *At. prisca*, (56.) *At. desquamata*, (57.) *Terebratula anisodonta*, (58.) *T. pugnus*, (59.) *T. reniformis*, (60.) *T. rhomboidea*, (61.) *T. acuminata*, (62.) *T. juvenis*, 63.) *T. sacculus*, (64.) *T. virgo*, (65.) *T. hastata*? (66.) *T. concentrica*, (67.) *T. flexistria*. (68.) *T. Mantiæ*. Gasteropoda:—(69.) *Acroculia vetusta*, (70.) *Euomphales serpens*. (71.) *Pleurotomaria monilifera*, (72.) *Murchisonia spinosa*, (73.) *Macrocheilus acutus*, (74.) *Bellerophon Woodwardii*, (75.) *B. Wenlockensis*, (76.) *Orthoceras cinctum*, (77.) *O. laterale*, (78.) *O. cylindraceum*, (79.) *Goniatites excavatus*, (80.) *G. serpentinus*. Crustacea:—(81.) *Calymene granulata*. (82.) *Cal. lævis*, (83.) *Asaphus granuliferus*.

Of these 83 species 7 (Nos. 3, 4, 5, 6, 8, 55, and 75) would be common, according to Mr. Griffith's lists, with the Silurian fossils of England and Wales, and another (No. 69) is given by Professor Phillips as common to the Silurian and carboniferous series of England. If we deduct these species, 10 other species are noticed in the South Devon rocks as also found in the Silurian series, namely:—

Polypiaria:—(1.) *Cyathophyllum turbinatum*, (2.) *Cy. cæspitosum*, (3.) *Porites pyri-*

---

* Notice respecting the Fossils of the Mountain Limestone of Ireland.

formis. Conchifera Plagymyona:—(4.) *Nucula ovata.* Conchifera Brachiopoda:—(5.) *Orthis compressa,* (6.) *Spirifera trapezoidalis* (7.) *Sp. cassidea,* (8.) *Terebratula Wilsoni,* (9.) *T. spherica.* Cephalopoda:—(10.) *Bellerophon trilobatus.*

According to this statement the proportion of the carboniferous limestone fossils in the Plymouth group, would be as 83 to 190, and of Silurian fossils, including those supposed common to this series and the carboniferous limestone, as 18 to 190. If the 8 species considered as common to the Silurian and carboniferous series be deducted, the proportions would be as 75 to 182 in the one case, and as 10 to 182 in the other, thus showing a much larger proportion of forms agreeing with the carboniferous than with the Silurian fossils. We have, therefore, when we compare the Plymouth group with the carboniferous and Silurian series, and with the Pilton and Petherwin groups, the following zoological evidence:—The Plymouth group is represented to contain, among the total number of species found in it, 44 per cent. of carboniferous limestone fossils, and 9 per cent. of Silurian; the Petherwin group, 57 per cent. of the former, and 11 per cent. of the latter; and the Pilton group, 63 per cent. carboniferous limestones fossils, and 10 per cent. Silurian.

No doubt the reasoning upon such points will depend upon the accuracy with which the forms found in the Plymouth and other Devonian groups may have been referred to others discovered in the carboniferous or Silurian series, as the case may be. As, however, viewed generally, there seems to have hitherto been a much stronger desire among palæontologists to multiply species than to find the same forms in rocks of different ages, even when deposited at periods not far removed from each other in geological time, we may probably regard these proportions of Silurian and carboniferous limestone fossils to the mass of those detected in the Plymouth and other Devonian groups as tolerably fair approximations, as far as the existing state of our knowledge may be made available.

When we discover any species of fossil animal in one locality above those beds in the geological series where we have found it cut off vertically in the detrital or calcareous accumulations of another, we necessarily infer that the conditions suited for the continuance of that species were prolonged in the one and not in the other locality, and hence, in South Devon we have to suppose a continuance of the needful conditions for the Silurian species found in it from subjacent or sufficiently near lower deposits equivalent in age to the Silurian accumulations on the north, in which the remains of these species are discovered. If we have regard to centres from which species were dispersed in that early geological period, and to conditions for their existence, there could scarcely have been the same fauna at the same time over different parts

of the general area; some species would be spread more commonly than others, many might take a long time to disperse from their centres, and the needful conditions in their original locality may have failed, so that they occupied a lower position among the deposits of the time in one place than in another. Viewing the subject in a general manner, we have to infer that, in the area of which South Devon formed a part, several corals, of kinds which were entombed in accumulations of the Silurian epoch (now buried beneath those forming the South Devonian rocks, or otherwise concealed), found suitable conditions for their continuance into times when molluscs, discovered amid the carboniferous limestones of England and Ireland, first began to appear on the south.

The mixture of species found in the Silurian and Carboniferous series, with many considered peculiar, led, as we have seen, to the inference that the South Devon beds were of a date equivalent to some part of the old red sandstone. From the increased knowledge we have lately had of the beds which may be considered as the passage of the old red sandstone into the carboniferous limestone, as well in Ireland as in South Wales, and in adjacent parts of England, we have endeavoured to point out, as not improbable, that in North Devon some part, at least, of the accumulations there exposed might be referable to that date. From the foregoing view of the proportion of carboniferous limestone and Silurian fossils to the total number of species obtained from the Plymouth group, there is much leading us to infer that in South Devon the accumulations under notice were not far removed from a similar geological date. We have yet to learn the vertical extent to which species may rise under favourable conditions. Limestones are common in South Devon, or, in other words, the conditions that suited the creatures to whose labours they are chiefly due, were common, and we can readily understand that the young fry of many species, finding localities fitted to them, prospered, and in proper time sent out their young, which would also continue to prosper under favourable circumstances. In this way many a species would rise upwards, some that were contemporaneous being less successful than others, so that horizontal zones would show the destruction of species in a very unequal manner.

Continuing to trace the Plymouth group westward, we soon observe the changes produced upon the marine animal life of the period by altered conditions, even in this minor area. The corals which formed thick beds of calcareous matter between the Tamar and the Teign, and especially between the Dart and the latter river, ceased to find conditions favourable for them, and those only which we may consider to have been suited to sand and mud, the latter calcareous, appear to

have flourished. Of this kind we may probably consider the *Turbinolopsis celtica.*

The continuation of the Plymouth group westward seems for some distance to have been chiefly mud or clay, sometimes gray, at others coloured red by peroxide of iron, here and there intermingled with sand and some calcareous matter. Good sections of this country will be seen up the Looe and Fowey rivers. At the former, slates containing calcareous matter are supported by arenaceous and argillaceous beds. This mixture of rocks continues towards Liskeard, where it is based apparently upon the arenaceous rocks of that locality. A section taken from Pencarrow Point, near Fowey, towards the granite of Carbarrow Hill on the north, exhibits a dip to the northward which would bring in higher beds in the direction of Boconnoc, showing the calcareous and fossiliferous beds of the Point supporting a mass of gray argillaceous slates, covered by red and variegated slates, and these by argillaceous slates, commonly gray.*

The same great group of beds may be seen continued from Fowey, by Mevagissey, Goran Haven, St. Michael, Veryan, St. Mawes, Falmouth, Mawnan, Anthony, and Trelowarren, to the west side of the Lizard district on the south of Helston. Many changes of detail are observable in this mass of accumulated sea-bottoms, and the detritus composing them must have been drifted and brought together in a very varied manner.† Although trappean rocks are mingled with these beds, they are not abundant. In the section shown by the line of coast from the Dodman Point to Portholland‡ we find a trappean rock intermingled in an interesting manner with a conglomerate, the size of some of the rounded stones in which are as large as a man's head; and, continuing the same line of coast, the Nare Head affords a section of trappean rocks, among which we find serpentine and diallage rock associated with conglomerate. The whole has the appearance of local igneous action among the gravels, sands, mud, and calcareous accumulations of the time and vicinity, the serpentine and diallage rock being included among the igneous rocks.§

Red and variegated beds traverse Falmouth harbour, and the mode in which the arenaceous rocks are mingled with the general mass of beds between Pendennis Castle and the Swan Pool, westward of the

* Report, &c. plate ii. fig. 2.

† For a detailed account of these rocks see Report in the Geology of Cornwall, &c., p. 78–86.

‡ The general section inland will be seen by reference to the Report, &c., plate ii. fig. 3.

§ Detailed sections of the coast between the Dodman and Portholland, and of the Nare Head round to Gerrans Bay, are given in the Report, &c., pp. 84, 85.

harbour, is illustrative of the manner in which the detritus has been accumulated. In many places the arenaceous beds are red. These variegated beds repose on gray or brown argillaceous slates, altered or metamorphosed near the granite. On the south the red or variegated beds come round from the Falmouth estuary, between St. Kea Church and Truro, towards St. Day.

A very interesting section presents itself on the south of the Helford river. Above an argillaceous slate, beds of conglomerate are seen to alternate with the slate, the rounded pebbles in the conglomerate chiefly consisting, with pieces of hornblende slate and rock, of quartz and portions of older slates and sandstones, occasionally of large size, some of the rounded fragments weighing nearly a quarter of a ton. The cementing matter of these conglomerates, which are well exhibited between Gillin and Carnmere, is chiefly arenaceous, and these ancient gravels are interesting from not containing fragments of the serpentine and diallage rock so near them on the south. The conglomerates and their associated beds can be easily traced inland to Trelowarren, the former becoming gradually less coarse, and partaking more of the appearance of a trappean conglomerate observed near the Nare Head, Veryan, of which indeed they appear, with those of the Nare Point, Anthony, to constitute the geological continuation. The calcareous character of part of the associated beds of Veryan is found in the calcareous slates and limestone of Betsey's Cove, south of Porthalla, so that occasionally, in the group of rocks extending from Plymouth to the Lizard district, carbonate of lime was mingled with the detrital accumulations of this geological period, at times and locally in quantity sufficient to form limestones. With the conglomerate series sandstones and dark carbonaceous shales are observed in the vicinity of Carne and Tregea, an interesting association if we regard the carbonaceous to have been derived from vegetable matter, thus locally mingled with the gravels, sands, and mud of the time.*

The conglomerates are not continued to the sea on the westward of Trelowarren, but are replaced by arenaceous rocks mingled with slates, so that these gravel accumulations, the large size of many of the rounded blocks pointing to no small power of water to move them, were local, though probably there was a general connexion between the conglomerates observed near Veryan and those of the Lizard district, where, near Trelowarren, vesicular trappean rocks occur in a manner pointing to their contemporaneous outflow amid the gravels, sands, and mud then accumulating near them.

* These carbonaceous shales were long since noticed by Professor Sedgwick.—Trans. of the Cambridge Philosophical Society, vol. i. p. 295.

to rest upon red slates and sandstones. Thus part, at least, of the limestones of this portion of Devonshire, rests upon, or is intermingled with, sandstones or slates, coloured red from a sufficient abundance of peroxide of iron.

Though calcareous matter is more scarce in the country between Plymouth and the district above noticed, including that of Chudleigh, Ashburton, Ogwell, and Totnes, there is no difficulty in seeing that the limestones in both are geologically connected. In this intermediate country we find beds, highly coloured by peroxide of iron, intermingled with the sandstones or slates, as the case may be; and at Plymouth the mass of limestone is seen to be covered by a considerable thickness of red sandstones and slates, the former often extremely hard.* We have evidence, therefore, that these limestone deposits are associated in such a manner with red sandstones and slates, among other rocks, that they may be observed in different localities either resting upon, included among, or covered by them.

With the sandstones and slates of other colours, also associated with these limestones, we have trappean rocks of a character which, though often showing intrusion among some parts of the general accumulation of beds, points to much local and contemporaneous volcanic action as a whole. Mr. Austen long since discovered organic remains in the volcanic ash, associated with more solid trappean rocks, upon which, as a floor, part of the Ogwell limestones were deposited,† and much ash and vesicular igneous rocks are intermingled with the great collection of beds of which the South Devon limestones constitute a part. A mass of ash and vesicular trap is observed to the eastward of the Yalberton limestone, and there is a small band of limestone apparently included

* Professor Phillips gives the following section of the Plymouth rocks in ascending order:—

1. Purple slaty rocks, highy laminated.
2. Plymouth limestones. Some beds mere coral masses. In upper part, red shales, yellow ochry beds, and purple masses of oxide of iron form a parting in the limestone.
3. Laminated schistose beds, irregular beds of trappean rock, with irregular and nodular admixtures of limestone.
4. Blue and gray schistose beds, with nodular limestone. Fossiliferous.
5. *a.* Carbonaceous and gritty beds. *b.* Argillaceous contorted schists. *c.* Calcareous laminæ.—Fossiliferous. *d.* Schists. *e.* Schists and thin grits. *f.* Laminated brown and red grits. *g.* Schists. *h.* Layers of nodular limestones, with Crinoidea.
6. *a.* Red grits, hard and coarse. *b.* Purple schists and fossils in bands. *c.* Red grits, with gray alternations, often ripple-marked on the surface; much resemble the beds of Martinhoe, North Devon.
7. Blue and gray shales, with thin calcareous bands.—Bovey Sand Bay.

Figures and Descriptions of the Palæozoic Fossils, &c., p. 201.

† Report, &c. p. 70. Mr. Austen, in his Memoir on the Geology of the South-East of Devonshire, states these beds to swarm with organic remains, chiefly Fenestellæ, columnar joints of Crinoidea, and shells of Brachiopoda.—Geol. Trans., Second Series, vol. vi. p. 471.

in it. A conglomerate containing quartz pebbles as large as a nut is also associated with this mass of vesicular trap and ash, pointing to the contemporaneous mixture of volcanic and aqueous products.

Mr. Austen directs attention to a very illustrative example of the contemporaneous intermixture of volcanic products with the rock formations of the time at Denbury, where the partings between the beds of limestone, composed chiefly of branching corals, "are of volcanic sand, which is easily removed, and we then obtain an upper surface studded with projecting stars and branches, as perfect as when the sand was thrown upon them and suspended the labours of the polyps."*

Many other cases of vesicular trap and ash occur, which, with the intrusive igneous rocks of more solid character, point to considerable volcanic action in this district, one more or less common to the accumulations of contemporaneous date, extending from it to Plymouth, Saltash, and St. Germans.†

Between the Tamar and the Teign, near Newton Bushel, including the Torbay district, we have a mass of accumulations which, though not marked by continuous bands of similar detrital or calcareous matter, still presents a certain general character as a whole. Sand and mud banks appear to have been contemporaneously mixed, and the one kind graduated into the other, so that now we find them in a consolidated state, as sandstones graduating into slates. Among these banks were coral reefs and accumulations of shells, sometimes more prevalent in

* Austen on the Geology of the South-East of Devonshire, Geol. Transactions, Second Series, vol. vi., p. 465.

† For greater detail of these rocks, and of the associated accumulations, see Report, &c., p. 62–76; Sedgwick and Murchison on the Physical Structure of Devonshire, &c. Geol. Trans., Second Series, vol. v. p. 649–662. These authors divide the South Devon rocks, in ascending order, into four groups:—1. The slate rocks bordering upon Dartmoor, many parts of which are indurated and altered in structure by the action of the granite. 2. A great zone of slates, more or less calcareous, with subordinate beds of limestone, the lower portion containing the Ashburton bands, the upper containing the great Plymouth and Tor Bay limestone. The upper portion also contains occasional beds of red slate and sandstone, which sometimes appear under the limestone, and sometimes seem to take its place along the lines of strike. 3. A great arenaceous group, containing many beds of red and variegated sandstone. 4. A group with many courses of soft, glossy slate, sometimes indurated, and used for roofing-slate, alternating with coarse quartzose bands, without any subordinate beds of limestone, and apparently without fossils. These four groups complete the ascending series, and are, together, of an enormous thickness.—Austen, Geology of the South-East of Devonshire, Geol. Trans., Second Series, vol. vi. p. 462–473. The following is Mr. Austen's view, in the descending order, of the relative superposition of the rocks noticed in his Memoir:—1. Coral limestone of Newton, Barton, Torquay. 2. Red sandstones and slates, extending from Paignton, Windmill Hill, near Berry Pomeroy, and across the Dart about Sharpham. 3. Limestones of Yalberton, Berry, and lower limestone of the Ogwell country. 4. Lower limestones, with contemporaneous trappean beds, ranging from Staple Hill, by Bickington, Ashburton, Buckfastleigh, and Dean Prior; separated from No. 3 by slate (with occasional lines of fine-grained fossil beds), fit for roofing-slate.

one part of the area than in another. At the same period volcanos locally existed, and threw out their ashes and their lava streams, forcing molten matter amid and into the cracks of the older deposits, which must have been often previously consolidated, as fragments of them are caught up, or the cracks in them formed, in a manner that justifies the conclusion. This action being continued irregularly, we have as the result very irregular minor accumulations above each other, due in no slight degree probably to the volcanic condition of part of this area at that geological time. Occasionally there was much peroxide of iron mingled with the detrital deposits now forming red sandstones and slates. These, however, are usually not very continuous, so that there is great difficulty in tracing them for any considerable distance, though, as a whole, they constitute a marked feature amid the general accumulations of the district.

Among the deposits southwards of the general range of calcareous country above noticed, there is also much red slate and sandstone, in some measure perhaps partly replacing it.* At Black Down and Morleigh Down light-coloured beds, often micaceous, pass into quartz rock, the cementing siliceous matter having destroyed, in a great measure, the granular character of the light-coloured sand originally deposited. A condition apparently due here, as in many other instances, to the introduction of silica amid the sand, under conditions favourable for the frequent and intimate union of the unfiltrated matter with the external portions of the grains of sand, drifted together so as to form a sandbank of nearly pure quartz. Much red mud was associated with the gray southward of these sandy accumulations, mingled with a minor proportion of sand; and the Start Bay sections show us that many minor masses, which were red in that direction, were gray westward, towards Bigbury Bay, so that peroxide of iron coloured the mudbanks but partially, red mud being probably drifted to them in one place, while the common gray mud was thrown down upon them in another.

As we have elsewhere remarked,† those who have seen coral reefs cannot but be struck with the resemblance many of the South Devon limestones present to such polyp-formed masses of calcareous matter. Their sudden termination and the presence of slates in their line of strike remind us of coral reefs against which mud has accumulated, the mud finally destroying the polyps, and enclosing the whole reef, with its associated molluscs, in a mass of clay or mud, now converted into hard

* See Report, &c., plate ii. fig. 1, where several miles of country south of the limestones of Dunwell are shown to be composed of sandstones and argillaceous slates, among which red beds are frequent. The same fact is shown by Professor Sedgwick and Mr. Murchison, Geol. Trans., Second Series, vol. v. plate li. figs. 5 and 6.

† Report, &c., p. 147.

slate. In this manner we can readily account for the disappearance of the many animal remains detected in the limestones and not found in the slates prolonged in the same line of strike, the muddy or arenaceous state, as the case might be, of the detritus drifted against the coral reefs not having been suited to the creatures that lived amid the corals.* In like manner we can understand the presence of the same creatures (the polyps having been successful in establishing their reefs), in the various patches of limestone isolated amid the sandstones and slates, even though not exactly in the same line of deposit, the young of the polyps fixing themselves favourably from time to time, and the young of the animals usually associated with them, flourishing in the same localities with them. And we should recollect that numbers of these isolated patches may be concealed from our observation, since we only see in section, and upturned, a minor portion of the sea-bottoms accumulated above one another at that time.

Mr. Austen, who has carefully studied the South Devon limestones with reference to their origin, observes, that very little personal examination would soon satisfy any one that the principal limestone masses have resulted from the labours of polyps, or existed as coral reefs; and remarks, that in the parish of East Ogwell each bed is entirely composed of branching corals in the position in which they grew. He observes, that, "among existing zoophytes the lamellated and cellulated orders seem to be the principal agents in constructing reefs, and their analogues mainly compose the Devonshire limestone."† The same geologist also remarks that there are certain local associations of generic and even specific forms observable. "Thus the limestone of Newton abounds in *Cyathophyllæ* and *Coscinoporæ*; that near Chercombe Bridge seems to have been almost exclusively constructed of *Favosites polymorpha*, and *Favosites spongites*; whilst about Denbury, *Favosites alveolaris* and other allied species are most abundant."‡

Adverting to the wide difference observable in the suite of organic remains obtained from the slates and from the coral limestones, though in many instances contemporaneous, as the natural result of the different habits of marine animals, Mr. Austen remarks, that "the Terebratulæ, which so swarmed about the reefs where they had the means of fixing themselves, that we find twenty-three species in the Newton quarry alone, are altogether wanting in the slate." The constancy of certain forms, as indicative of similar conditions, is pointed out, and *Fenestellæ*, *Turbinoliæ*, *Pleurodyctium problematicum*, &c., are instanced as ranging

* For further remarks on this subject, applicable to the district, see Report, &c., p. 147–149.

† Geology of the South-East of Devon. Geol. Trans., Second Series, vol. vi. p. 465.

‡ Ibid.

less so in North Devon, and in still more diminished quantity in South Devon and Cornwall. Thus the marine animals of that day would be less interrupted on the south than on the north, many leaving their accumulated remains in localities favourable to their existence, so as to constitute beds of limestone, the part of the general area occupied by South Devon having been that where the most favourable conditions presented themselves.

Taking the general mass we find the comminuted remains of pre-existing rocks (to be measured in cubic miles) borne from some land at a reasonable distance, and distributed in the form of many banks of mud, sand, and gravel, as such detritus now is, sea-bottom accumulating upon sea-bottom; the higher beds of the old red sandstone on the north showing unequivocally that older beds of the same mass of rock were broken up after their deposit and consolidation, and therefore under the needful conditions, after a lapse of sufficient time, to convert sand into sandstone. According to favourable circumstances and their habits, animals were variously distributed over the sea-bottom of the time, their remains being entombed as one sea-bottom accumulated over that which preceded it. In some places coral reefs were formed, and amid and around them molluscs and other animals found localities suited to their mode of life. As these reefs became covered by detrital accumulations, new colonies were established elsewhere, and thus beds of limestone, composed of the remains of corals and of animals which lived, as it were, in society with them, occurred sometimes in one place, sometimes in another, becoming so enveloped as the detrital accumulations increased that the present upturned edges of these ancient sea-bottoms show them to have been irregularly dispersed at different times.

Where circumstances were favourable, as they appear to have been on the south, the animal life of older geological times and sea-bottoms was continued upwards amid new creatures formed to suit the seas, mud, and sand-banks of the time, a general change of animal life taking place. While gravels were abundant on the north, and their mode of occurrence points to much forcing of detritus along the bottom, we have, on the south, more accumulations which may be considered as formed by the deposit of matter from mechanical suspension, there appearing greater evidence in that direction, though gravel-banks were not wanting, of the more quiet action of water and the distribution of finer detritus, as if by tides. Animal life was less interrupted, apparently, on the south than on the north, and local volcanic action was confined to the south; so that, assuming the Cornish and Devonian rocks to be of the geological age above supposed, a view according generally with that taken by the various geologists above mentioned,

we should, in a very limited area, have a good example of the lithological and zoological modifications effected by difference of conditions at equal geological times.*

* As it formed no part of the plan adopted for this memoir to take general views of the probable condition of very extensive areas at equal geological times, but rather to show modifications and changes effected over a limited one, reference has not been made either to the extension of the Old Red Sandstone in the United Kingdom, or to the beds considered equivalent to the Devonian system in other parts of Europe. In 1839 Mr. Austen, after noticing the similarity of certain organic forms in the South Devon rocks with those in the south of Ireland, was guided by the identification of about forty species to suggest that the South Devonian deposits, and others in the Rhine and Eifel countries, were equivalent (Report of the British Association, 1839, p. 69, and Geology of the South-East of Devonshire, Geol. Trans., Second Series, vol. vi. p. 465). In 1840 Mr. Lonsdale inferred, with Mr. Murchison, that there were beds at Boulogne equivalent to the Devonian rocks. On the Age of the Limestones of South Devon, Geol. Trans., Second Series, vol. v. p. 736. In 1840 Professor Sedgwick and Mr. Murchison read a Memoir before the Geological Society, on the Distribution and Classification of the Older or Palæozoic Deposits of the North of Germany and Belgium, and their Comparison with Formations of the same age in the British Isles, published in the Geol. Trans., Second Series, vol. vi. p. 221, in which they concluded that there were equivalents of the Devonian rocks between the carboniferous limestone above and Silurian rocks beneath in those countries. In 1841 Professor Phillips compared the Devonian fossils with those of the Eifel and Bensberg districts, showing considerable resemblance between them.—Figures and Descriptions of the Palæozoic Fossils of Cornwall, Devon, and West Somerset.

In connexion with the Memoir of Professor Sedgwick and Mr. Murchison, Viscount D'Archiac and M. de Verneuil, who had previously devoted great attention to the study of Palæozoic forms, published (Geol. Trans., Second Series, vol. vi. p. 303, read December, 1841) an elaborate memoir "On the Fossils of the Older Deposits in the Rhenish Provinces, preceded by a General Survey of the Fauna of the Palæozoic Rocks, and followed by a Tabular List of the Organic Remains of the Devonian System in Europe." This treatise is replete with valuable matter. No doubt many conclusions as to the distribution of organic remains, vertically and horizontally, when masses are taken, must depend upon the limits supposed to bound such masses; and when a sequence of changes is observed throughout several superimposed masses, the artificial boundaries of one locality may not be the same with those in another, so that equal things may not be always compared. Independently, however, of these considerations, and of the uncertainty of many supposed equivalent rocks situated far distant from each other, and considered to have been formed at exactly equal geological times, which may require further research, there is a philosophical tone throughout the memoir deserving of every attention.

Viscount d'Archiac and M. de Verneuil conclude their remarks by observing that, "if certain divisions, such as the *Gasteropoda*, the *Monomyaria*, the *Dimyaria*, and the *Annelides*, had comparatively few representatives in the ancient seas, others, such as the *Polypiaria* and the *Cephalopoda*, are not less plentiful than in any of the following periods—and some, such as the *Brachiopoda* and the *Crinoidea*, are infinitely more varied. Lastly, if the development of Palæozoic organism be considered relatively to the thickness of the beds or duration of the epoch, we shall see,—1st, that the total number of species always increases from below upwards; 2nd, that the progression is very different in each order and in each family, and that this progression is even frequently inverse, either in the different orders of the same class or in the various genera of the same order. If, on the other hand, this development of the Palæozoic creation be considered relatively to its horizontal extent, or geographically in relation to space, it will be seen,—1st, that the species which are found in a great number of localities, and in very distant countries, are almost always those which have lived during the formation of several successive systems; 2nd, that the species which belong to a single system are rarely observed at great dis-

Carboniferous or Mountain Limestone.

We have now to consider a most material change in the deposits, one marked by some great alteration of conditions, over part of the area at present occupied by South Wales and South-western England. The sections of West Angle (p. 61), of Caldy Island (p. 62), and of Dean Forest (p. 58), will have shown the modifications effected in the accumulations of the last part of the old red sandstone period in those localities, modifications exhibiting somewhat of an uniform general character, though many minor variations are observable.*

The highly ferruginous character of the sedimentary matter has disappeared, and, as this happened, marine creatures entered upon the space previously so ill-suited to their well-being. As we might expect, fish were chiefly those which first availed themselves of the altered conditions, their fæces and bones marking their somewhat long continued presence in the water before many molluscs found their way to accumulations which had ceased to be noxious to them. The following section, on the north of one previously given (p. 61), will be useful in showing not only the progress of some of these changes of deposit, but also the modifications observable in a very short distance.

Section of the lower part of the Carboniferous Limestone in West Angle Bay (north side) Pembrokeshire.

		Ft.	In.
1.	Subnodular limestone and calcareous shale	28	0
2.	Nodular limestone with shale	26	0
3.	Calcareous shale and subferruginous limestone (*coprolites* and *fish-palates*)	55	0
4.	Solid subnodular and ferruginous limestone	5	0
5.	Calcareous shales and limestones (*coprolites*)	55	0
6.	Calcareo-argillaceous shales with a few calcareous bands, mostly *coprolitic*	40	0
7.	Limestone, with a few thin bands of shale, the top brown or reddish, with small quartz pebbles	23	6
8.	Argillaceous and sub-calcareous shales, with black nodules (a few *crinoidal* lines)	15	0
9.	Calcareous gray, and yellow conglomerate (quartz pebbles)	2	0
10.	Argillaceous shale (a few *encrinites*)	10	0
11.	Shales not calcareous, and thin crinoidal limestone	8	6

tances, and that they then constitute local faunæ, peculiar to certain countries; whence it results that the species really characteristic of a system of beds are so much the less numerous as the system is studied upon a vaster scale." p. 334.

* This will be well seen by comparing the Vertical Sections, sheet 12, where the junction of the old red sandstone with the carboniferous limestone is shown at West Angle, Skrinkle Haven, and Caldy Island, Pembrokeshire; Clydach, Monmouthshire; Dean Forest, Gloucestershire; Clifton, Bristol; and at the Mendip Hills, Somerset.

	Ft.	In.
12. Crinoidal limestone	0	5
13. Thin pale shale, and sub-calcareous *fossil band*	0	6
14. Slightly calcareous sandstone (*coprolitic*)	0	8
15. Nodular crinoidal limestone	0	3
16. Slightly calcareous sandstone (*coprolitic*)	0	6
17. Brownish-red sandstone, upper part and base partly calcareous, the lower portion yellowish	6	8
18. Red ochreous bed, with pebbles	2	8
19. Gray shale, partially calcareous, and thin calcareous sandstone	9	0
20. Gray calcareous sandstone	1	0
21. Sandstone, beneath, red and subcalcareous, above, gray and calcareous (on the surface, *fish-teeth* and *bones*)	4	6
22. Gray calcareous band	0	6
23. Red marly sandstone	10	0
24. Gray sandy limestone	2	6
25. Soft gray marls	1	0
26. Grey sandstone, sub-calcareous and nodular	2	6
27. Red sandy marls	1	0
28. Hard sandstone, the uppermost foot is mottled blue	7	9
29. Sandy red marls	3	6
30. Hard red sandstone	0	8
31. Red sandy marls	2	3
32. Red sandstone	0	3
33. Mottled red and gray sandstone	0	3
34. Red sandstone	3	0
35. Gray shales and thin bands of sandstone (*plants in the shale*)	8	6
36. Hard sandstone	0	3
37. Gray shale	3	0
38. Red sandstone		

The discovery of the plants, in No. 35 of this section, is interesting as adding another instance of their occurrence in England and Wales at this geological period, and, when taken in connexion with the plants found in Ireland (p. 55), in accumulations of the same relative date, affords additional evidence that the area has been very extensive over which they were distributed at a time immediately preceding the change productive of those thick accumulations of calcareous matter which cover so many thousand square miles in the United Kingdom.*

As exhibiting the multitude of minor alterations effected in the accumulations formed during the change from the highly ferruginous deposits of the old red sandstone of South Wales and adjoining English counties to the limestones which succeeded them, the following detailed section, made by Mr. Ramsay with great care for this purpose, in a highly favourable locality on the coast of Pembrokeshire, will be found valuable.

* Viewed also in connexion with the earlier accumulations of the matter of coal in Northern England and Scotland than in Southern England, these plant-bearing beds offer considerable interest, aiding our inquiries respecting the various modifications which may have influenced the general conditions of the time.

Section of the Junction of the Carboniferous Limestone and Old Red Sandstone at Skrinkle Haven, Pembrokeshire.

	Ft.	In.
1. Thin bedded limestone	6	0
2. Shale, thin laminæ, very calcareous	1	4
3. Limestone, shells in thin layers, with very thin partings of shale, and several black chert layers; encrinites abound	53	6
4. Calcareous shale	0	6
5. Limestone, with thin lines of shale	2	4
6. Calcareous shale	1	8
7. Limestone	0	4
8. Calcareous shale and limestone	1	4
9. Limestone	1	6
10. Calcareous shale, with thin lines of limestone	0	4
11. Limestone, with thin beds of shale	3	0
12. Calcareous shale	0	10
13. Limestone	1	8
14. Calcareous shale, with very thin beds of limestone	0	6
15. Limestone	1	0
16. Calcareous shale and thin beds of limestone	1	0
17. Limestone and calcareous shale	1	8
18. Calcareous shale, with thin beds of limestone	1	8
19. Limestone	0	9
20. Calcareous shale, with thin beds of limestone	1	11
21. Limestone, with thin beds of calcareous shale	11	0
22. Calcareous shale	10	0
23. Limestone	0	11
24. Calcareous shale	12	0
25. Limestone	1	0
26. Calcareous shale, with thin beds of limestone	11	6
27. Limestone	1	0
28. Calcareous shale, with three beds of limestone, each six inches thick	27	6
29. Conglomerate	0	3
30. Calcareous shale and thin beds of limestone	22	6
31. Harder ditto	4	4
32. Calcareous shale and thin beds of limestone*	19	6
33. Calcareous shale, with thin bands of limestone	4	8
34. Limestone	1	6
35. Dark arenaceous shale, very slightly calcareous	2	2
36. Limestone	1	9
37. Shaly limestone, *shells*, and *remains of fish*	4	4
38. Highly calcareous shale, with nodules and thin beds of limestone	1	3
39. Compact limestone	1	0
40. Calcareous shale	1	3
41. Hard fossiliferous limestone	1	8
42. Limestone and shale, interstratified with *shells*, and *remains of fish*	2	3
43. Highly calcareous shale with thin beds of limestone	2	2

* In this part of the section the calcareous shale beds in the cliff, when traced to a small promontory within high-water mark, assume a harder texture, appearing much like the common limestone.

There is very hard limestone, oolitic, in the upper and lower beds. A cave pierces this promontory at right angles to the strike; there the rock is very hard. Further inland is another cave where, in the interior, the beds begin to assume a shaly aspect.

	Ft.	In.
44. Compact limestone, *shells, fish*, &c.	0	9
45. Highly calcareous shale	2	7
46. Limestone	0	10
47. Calcareous shale	0	8
48. Limestone	2	0
49. Calcareous shale	0	8
50. Limestone, with thin beds of shale	2	4
51. Calcareous shale	1	2
52. Limestone	1	0
53. Limestone and calcareous thin-bedded shales	1	0
54. Limestone	1	7
55. Calcareous shale	0	4
56. Limestone	1	8
57. Calcareo-argillaceous shale, with thin beds of limestone. Here calcareous matter begins to become less plentiful	1	0
58. Limestone	0	6
59. Fine calcareo-arenaceous shale	0	7
60. Limestone (*shells, fish*)	0	9
61. Calcareo-arenaceous shale	1	7
62. Limestone (*fish*)	0	6
63. Calcareo-arenaceous shale, with thin beds of limestone	3	9
64. Limestone	0	8
65. Shale, calcareo-arenaceous, with thin beds of limestone	3	6
66. Highly calcareous shale, with thin bands and nodules of limestone	2	0
67. Limestone (*shells, fish*)	1	3
68. Areno-calcareous shale, with six thin beds of limestone (*shells, fish*)	3	8
69. Argillo-calcareous shale, with thin beds of limestone	3	0
70. Limestone (*fish, encrinites*, &c.)	2	0
71. Arenaceous shale and thin beds of yellow sandstone, much obscured by rubbish	22	9
72. Yellowish-gray sandstone, *with traces of decomposed shells*	1	3
73. Arenaceous shale, with thin beds of sandstone	3	7
74. Sandstone	11	0
75. Arenaceous, argillo-arenaceous, and argillaceous shales, with thin beds of yellow and gray sandstone; the lowest beds are slightly calcareous	26	6
76. Argillaceous shale with thin beds of limestone, containing the remains of *shells, fish*, and *coprolites*; also beds of slightly calcareous sandstone containing *coprolites*	24	4
77. Limestone	1	1
78. Limestone and shale	1	10
79. Calcareous sandstone, with *encrinites*, alternating with beds of reddish sandstone, without fossils	1	6
80. Limestone, with very thin beds of shale, the limestone granular	10	0
81. Gray argillaceous shale, with very thin beds of arenaceous limestone (*coprolites, encrinites, orthides*)	12	9
82. Arenaceous shale, with thin beds of sandstone	11	4
83. Gray sandstone	0	6
84. Yellow and red sandy marls	0	9
85. Light gray sandstone	0	10
86. Dark red marls	5	0
87. Sandstone	0	4
88. Dark red marls	5	0
89. Red sandstone, with thin beds of red marl	1	9

		Ft.	In.
90.	Red marl	1	0
91.	Yellow sandstone	0	10
92.	Red and yellow sandy marls and sandstones	5	10
93.	Much obscured, but apparently red and yellow soft marly sandstone	13	0
94.	Soft yellow sandstone	3	0
95.	Red marl	2	6
96.	Sandstone, red and yellow mixed	2	0
97.	Yellow sandstone	2	0
98.	Red and yellow sandstone	4	6
99.	Dark and light red sandstone, in beds from one to two inches thick, with thin intervening marls	6	0
100.	Red marl	0	3
101.	Red sandstone and sandy marls	3	4
102.	Red marl, with two beds of yellow sandstone, one inch thick	3	6
103.	Red sandstone, with thin red marls	6	6
104.	Light red sandstone	0	8
105.	Red marls, with thin beds of yellowish sandstone	2	0
106.	Hard sandstone	0	7
107.	Red marls, with beds of sandstone like the preceding	8	0
108.	Hard sandstone	2	8
109.	Obscured, but apparently similar to the last few alternations	7	7
110.	Coarse sandstone	5	6
111.	White sandstone, mostly obscured	13	9
112.	Very red soft marly sandstone	3	3
113.	Sandy conglomerate	4	7
114.	Red and yellow sandstone	1	10
115.	Red marls and red marly sandstone	15	9
116.	Light red hard sandstone	0	2
117.	Red marl	5	8
118.	Coarse white hard sandstone	3	10
119.	Red and yellow beds of sandstone, alternating with thin beds of soft yellow and red marls	13	3
120.	Conglomerate, hard	2	5
121.	The same, but very soft	1	9
122.	Yellow and red sandstone, shaded into each other about the middle of the bed	2	7
123.	Soft, marly, variegated red and yellow sandstone	3	0
124.	Soft sandy red and yellow clay	1	6
125.	Soft sandstone, mostly red, but merging into yellow in the upper beds	5	1
126.	Hard conglomerate	1	10
127.	Red sandstone, with very thin red marls	4	2
128.	Soft red marl	1	0
129.	Red sandstone, with a few thin beds of marl	10	7
130.	Red marl	13	4
131.	Red sandstone	1	0
132.	Much obscured, but apparently red and yellow sandstone and marl	57	6
133.	White sandstone, succeeded by red marls, conglomerate, and cornstones		

We here see that, after the alternations of red mud and sand, mingled occasionally with gravel, the iron was no longer in sufficient abundance to afford a red tint to all the accumulations, yellow becoming mingled with the red, while some sands were entirely without colouring

matter, the resulting sandstone being composed of little else than colourless quartz grains agglutinated together by colourless silica. Calcareous matter afterwards became intermixed with the mud, no longer impregnated with an abundance of peroxide of iron, and as soon as this calcareous matter appears we discover the remains of animal life, the droppings of fish, with encrinites and orthides. The limestones interstratified with the argillaceous shales are argillaceous also, and remind us of the same waters holding bicarbonate of lime in solution, with fine mud in suspension, the carbonate of lime being afterwards thrown down from a loss of carbonic acid, sometimes dispersed through the mud, at others deposited in sufficient abundance, and by uniting with a minute quantity of mud, to form a thin band of argillaceous limestone. These conditions alternated, and interstratified shales and limestones were the result. After a small accumulation, sandy drift became intermixed with the shale and limestones, sometimes mingled with the mud, at others constituting thin sand-banks. The existence of life was not, however, seriously interrupted; indeed, by comparing the sections, the non-fossiliferous beds are found to be mere patches mixed with the general mass, so that the seas now teemed with fish, radiata, and molluscs. Alternations of the conditions noticed, the sandy matter disappearing, continued to the height of 386 feet, when the limestones were produced, with very little interruption, for a considerable thickness, one in the neighbouring Island of Caldy seen to be (Nos. 1, 2, 3, 4 of the following section) about 1900 feet. The whole depth of the carboniferous limestone beds in Caldy Island appears to be 2300 feet, there being a slight increase of the lower beds between it and Skrinkle Haven.

Section of the Carboniferous Limestone, Caldy Island, Pembrokeshire.

	Feet
1. Beds, usually thick, of compact gray and brown limestones, fossil corals common	350
2. Similar beds, one to four feet thick	700
3. Same beds, becoming thinner	360
4. Beds from seven or eight inches to one foot thick, containing many *spirifers*, and abounding in broken *encrinites*	485
5. Limestone and shales	30
6. Thin-bedded limestone	16
7. Shales, with a few beds of limestone	12
8. Calcareous shales	37
9. Thin-bedded argillaceous limestone	26
10. Limestone, chiefly thick-bedded	95
11. Slaty and yellowish slightly coherent sandstones	67
12. Brown shales with a few bands of impure limestone	29
13. Brown argillo-arenaceous and fossiliferous beds	90

This section, so valuable for being very easily seen, shows us that after the mud ceased to be thrown down, the accumulations which sub-

sequently took place were chiefly composed of broken encrinites, and that myriads of individuals must have appropriated, probably from the adjacent waters, the carbonate of lime for their harder parts, which now form the principal mass of limestones 485 feet thick. Wherever weathered, these beds seem composed of little else than animal remains. Examining these carefully, they do not appear to have been transported any considerable distance: on the contrary, they have more the character of an accumulation (slightly checked from time to time, thus forming distinct beds) of the harder parts of animals which have existed on the spot or at no great distance, thus constituting great banks of such remains, at depths too considerable to be much exposed to friction from the action of waves or streams of tide.

We shall have a good idea of the great thickness of these encrinital accumulations if we take a chart of the Irish Sea, and observe that the depth, 80 fathoms, of this mass of animal remains is too considerable to have been formed in such a sea. Even a large part of the English Channel would be unable to contain such a thickness of them. Though so thick on the south of Pembrokeshire, this accumulation of calcareous matter, the work chiefly, as regards its component parts, of animal life, fines off in the same district, and within a few miles, so as to be concealed by an overlap of coal measures, itself having overlapped the old red sandstone, so that one after the other they became extended over the edges of the subjacent deposits, showing a change of the accumulations from a sinking of the bottom, or an alteration in the line of drift in a particular direction. Under such conditions it becomes interesting to observe whether the upper or lower parts of the mass have been most extended. From the general tendency of the upper to overlap the lower accumulations, we should anticipate that the upper beds would be spread further than the lower, and this would appear to be the case, for the latter are those which have remained within the minor area.

This decrease of the carboniferous limestone on the north of its general prolongation in South Wales, is to be observed during its whole range in that direction, the chief thickness keeping, as it were, an eastern and western general strike; so that in the Mendip Hills, and in the neighbourhood of Bristol, the thickness does not materially differ from that observed in South Pembrokeshire. It is interesting also to observe, that the general characters remain much the same; the passage beds into the old red sandstone, the abundance of encrinites in the lower beds, and the more frequent occurrence of corals in the upper part. Fortunately the gorge of the Avon, near Bristol, affords an excellent section of the carboniferous limestone, as there developed. It has often been noticed, more particularly by Dr. Buckland, Mr. Cony-

beare,* Dr. Bright,† and Mr. Cumberland.‡ The following is a very detailed examination of it by Mr. David Williams, of the Geological Survey, and strikingly exhibits the multitude of modifications and changes which have taken place during the accumulation of this mass of matter, of which the whole thickness is more than 4000 feet, consisting of the hard sandstones, which have been commonly termed millstone grit, 950 feet; of carboniferous limestone, 2,338 feet; and of an upper portion of the old red sandstone, amounting to 768 feet.

Section of the lower part of the Coal Measures, of Carboniferous Limestone and of Old Red Sandstone, beginning at the Brandon Hill or Millstone Grits, and continued down the Avon, near Bristol.

	Ft.	In.
1. Hard sandstone, commonly red, known as Millstone Grit or Farewell Rock	950	0
2. Red marl	0	4
3. Quartzose sandstone	0	4
4. Red marl	1	0
5. Hard and compact red quartz rock	3	0
6. Red shale	0	3
7. Compact grit, ferruginous specks	4	0
8. Impure limestone	2	0
9. Compact siliciferous limestone (very fine-grained)	1	7
10. Compact grit, spotted with iron	1	3
11. Compact, crystalline red and gray limestone	12	5
12. Red marl (a parting)		
13. Gray compact siliciferous limestone	1	7
14. Red marl	0	1
15. Compact gray limestone	2	3
16. Sandstone, with partings of red marl	1	6
17. Compact red and gray siliciferous limestone	4	6
18. Red marl	0	3
19. Hard gray, and red limestone	2	2
20. Red marl, a thin parting only	0	0½
21. Light gray, compact quartzose sandstone	1	0
22. Compact gray siliciferous limestone	5	0
23. Red and green marl	2	2
24. Red siliciferous limestone	2	2
25. *Unseen* (supposed to be limestone shale and grit alternating)	74	3
26. Quartzose sandstone, in 13 thin beds	8	0
27. Black and gray carbonaceous marl	2	0
28. Thin-bedded shaly sandstone	2	0
29. Red marl	1	0
30. Sandstone, in 8 beds.	4	0
31. Red and blue argillaceous sandstone	1	0

* Observations on the South-Eastern Coal District of England, Geol. Trans., Second Series, vol. i.

† Geol. Trans., First Series, vol. iv.

‡ On the Limestone Beds of the River Avon, near Bristol, Geol. Trans., First Series, vol. v.

	Ft.	In.
32. Gritty argillaceous sandstone	0	5
33. Blue, laminated argillaceous sandstone	3	7
34. Compact limestone, oolitic (*Spiriferæ* and *Productæ*)	1	0
35. Limestone (two beds)	0	9
36. Variegated shales	0	6
37. Compact limestone	0	6
38. Gray and black shales	1	2
39. Nodular, indurated marl	0	7
40. Compact limestone	0	5
41. Undulating beds of blue and red nodular shale	1	3
42. Oolitic limestone	6	0
43. *Unseen. Dip, above and beneath,* 37° (supposed to be limestone, shale, and grit, alternating)	14	3
44. Light gray and red marl, with shattered sandstone	4	0
45. Thick and thin bedded sandstone, with thin partings of red marl	6	9
46. Red and light gray marl	6	0
47. Light gray concretionary marl, calcareous	1	3
48. Light gray quartzose sandstone	1	0
49. Thin-bedded sandstone, with marl	1	0
50. Red and gray siliciferous limestone	1	1
51. Red and light gray marl	0	2
52. Light gray sandstone, calcareous, quartzose, fine-grained, and hard	1	6
53. Siliciferous limestone	3	4
54. Red and gray siliciferous limestone (*Caryophyllia*)	3	5
55. Quartz rock (irregular)	0	4
56. Red marl	1	3
57. Red quartzose sandstone	3	2
58. Quartzose sandstone, fine-grained and hard	8	6
59. Shale parting		
60. Red and gray coarse granular limestone	1	6
61. Light gray compact limestone, coarse-grained, *Productæ*, *Encrinites*, &c.	5	3
62. Light gray coral bed (*Spiriferæ*)	0	9
63. Light gray oolitic limestone	2	0
64. Indurated marly bed (*Fossiliferous*)	1	0
65. Light gray oolitic limestone	4	6
66. Red limestone, with from 1 to 6 inches of *Corals*	1	0
67. Coarse light gray oolitic limestone, 3 to 12 inches of *Corals* on the bottom	10	0
68. Compact gray limestone (*Bellerophons*)	1	1
69. Concretionary marl and limestone, *Coral top and bottom*	0	6
70. Compact gray oolitic limestone (*Terebratulæ*, *Spiriferæ*, and *Productæ*)	8	6
71. Concretionary marl	0	2
72. Gray compact limestone (*fossiliferous*)	6	6
73. Concretionary limestone (*Productæ*)	0	6
74. Compact gray limestone (*Terebratulæ*, *Spiriferæ*, and *Productæ*)	2	6
75. Impure shaly limestone	0	9
76. Impure limestone	0	6
77. Limestone, *with Corals*, and shales	0	6
78. Compact gray limestone (*fossiliferous*)	1	3
79. Impure concretionary limestone, alternating with shales	2	9
80. Compact gray limestone	2	7
81. Light gray, coarse-grained limestone, with small grains of quartz	2	0

	Ft.	In.
82. Light gray oolitic limestone (*Encrinites*)	1	0
83. Dark argillaceous shale	0	3
84. Compact limestone	2	0
85. Compact dark gray limestone, fine-grained, and hard	12	0
86. Sandstone, quartzose, and hard	3	7
87. Sandstone, highly ferruginous	3	0
88. Compact grit	3	0
89. Red marl	0	8
90. Carbonaceous shale, with grains of coal	1	0
91. Underclay, with *Stigmaria ficoides*	5	6
92. Thin beds of sandstone, tinged red by iron	0	6
93. Red marl	1	3
94. Concretionary white oolitic limestone	1	2
95. Fine-grained red quartzose sandstone	1	2
96. Red argillo-arenaceous shale	1	4
97. Reddish gray oolitic limestone, with quartz pebbles	1	3
98. Red shale	0	3
99. Impure siliciferous limestone, with quartz pebbles	1	7
100. Red quartz rock	1	0
101. Red shale (thins out)	0	6
102. Hard quartz rock, tinged red by iron	6	6
103. Red shale, and very thin-bedded sandstone	1	6
104. Concretionary oolitic limestone, with pebbles of quartz on the top	3	0
105. Impure limestone, with embedded pebbles of quartz	0	6
106. Coarse grained red and blue oolitic limestone (*fossils*)	2	7
107. Red quartzose sandstone, with 6 inches of pebbles on the top	1	10
108. Thick and thin-bedded red quartzose sandstone	3	7
109. Close-grained oolitic limestone, coloured by oxide of iron, and containing on the top small rounded pebbles of white quartz	2	0
110. Red shale, with white indurated marl	9	0
111. Light gray limestone, slightly oolitic, and cemented with red and gray marl	8	8
112. Compact thin-bedded oolitic limestone	13	0
113. Close-grained sandstone, with partings of red shale and small veins of oxide of iron	7	0
114. Gray limestone, close-grained, siliciferous, and coloured red with peroxide of iron	2	0
115. White and red concretionary marls	4	6
116. Concretionary limestone	3	0
117. Gray limestone, coloured red by peroxide of iron	6	0
118. Concretionary limestone (*Producta gigantea* and *Corals*)	1	8
119. Compact gray limestone, *Corals*, *Productæ*, &c., upon the upper beds	3	0
120. Light green marl	1	0
121. Red concretionary shale (*Productæ*)		
122. Red and gray limestone	2	6
123. Hard brown and red shale (*Producta gigantea*)	1	0
124. Impure brown limestone	1	1
125. Light red shale (*Spiriferæ*, *Producta gigantea*)	0	8
(*Base of upper grits and limestone.*)		
126. Compact gray limestone (in three beds)	25	0
127. Red shale	1	0
128. Concretionary limestone	4	0
129. Gray limestone	15	0
130. Red shale, irregular (*fossiliferous*)	1	0

		Ft.	In.
131.	Light gray limestone.	28	0
132.	Hard red marl.	0	6
133.	Light gray limestone	7	0
134.	White limestone (*a coral bed*)	9	6
135.	Red shale	0	3
136.	Light gray limestone, compact with *Productæ* and *Corals*	6	6
137.	Red and gray marly shale	0	6
138.	Light gray limestone, compact	9	0
139.	Concretionary marly limestone	3	0
140.	Soft gray limestone	14	0
141.	Concretionary marly limestone, tinged with peroxide of iron	3	0
142.	Light gray limestone	16	0
143.	Oolitic limestone	6	0
144.	Shale	0	4
145.	Impure siliciferous limestone	2	0
146.	Shale	0	3
147.	Impure limestone, irregular, in three beds (*Productæ*)	2	2
148.	Concretionary marly limestone	1	9
149.	Light gray limestone	4	0
150.	Parting of shale (irregular)	0	1
151.	Gray limestone, compact	3	0
152.	Shale	0	2
153.	Impure limestone	4	4
154.	Shale	0	6
155.	Impure limestone	2	6
156.	Carbonate of lime and shale	1	2
157.	Light gray limestone	8	0
158.	Thick-bedded gray limestone (*Corals*)	70	0
159.	Gray limestone	6	0
160.	Shale	0	3
161.	Dark gray limestone (*fossiliferous*)	24	0
162.	Dark gray limestone	57	0
163.	Light gray limestone	22	0
164.	Light gray thick-bedded limestone	40	0
165.	Light gray limestone, *Corals* and *Productæ*	26	0
166.	Gray limestone, in two beds (*Coral beds*)	24	0
167.	Thick-bedded gray limestone	109	0
168.	Light gray limestone	10	0
169.	Gray and brown limestone	6	4
170.	Black and gray limestone (*a coral bed*)	4	6
171.	Dark gray limestone, blackish on the top	6	6
172.	Dark gray and blackish limestone	28	0
173.	Shaly limestone	0	4
174.	Gray limestone	10	0
175.	Light and dark gray limestone, irregular at the bottom	50	0
176.	Dark gray limestone	9	6
177.	Black limestone	4	6
178.	Black and gray limestone	26	0
179.	Red shale	0	4
180.	Gray limestone	7	0
181.	Light and dark limestone, in thick and thin beds	100	0
182.	Brown argillaceous limestone	0	4
183.	Brown shale	0	2
184.	Brown argillaceous limestone	0	6

		Ft.	In.
185.	Brown calcareous shale	0	4
186.	Brown argillaceous limestone, with thin bands of calc. spar	0	6
187.	Brown shale, with thin bands of calc. spar	0	3
188.	Black and brown argillaceous limestone, impure, very hard (*Corals*)	0	10
189.	Brown impure limestone	0	6
190.	Brown shale	0	2
191.	Black limestone, with *Lingulæ;* fracture, subconchoidal	0	7
192.	Black and brown carbonaceous shale	0	7
193.	Black argillaceous limestone	2	5
194.	Black shale (laminated)	0	4
195.	Black argillaceous limestone	0	9
196.	(Ground unseen), probably argillaceous limestone	4	3
197.	Dark gray limestone, nearly black	2	4
198.	Black and brown argillaceous limestone, alternating with shale	1	2
199.	Black argillaceous limestone	1	2
200.	Black shale	0	1
201.	Dark gray argillaceous limestone, nearly black	0	4
202.	Brown shale	0	2
203.	Brown argillaceous limestone	0	11
204.	Brown shale	0	1
205.	Brown argillaceous limestone	0	6
206.	Black argillaceous limestone	0	5
207.	Red and brown shale	0	2
208.	Black and green shale	0	6
209.	Brown and green shale	0	2
210.	Black argillaceous limestone	0	4
211.	Black and brown shale, irregular	0	1
212.	Black argillaceous limestone, irregular	1	0
213.	Shale, irregular	0	2
214.	Black argillaceous limestone	1	1
215.	Brown shale	10	0
216.	Very dark gray argillaceous limestone; fracture, subconchoidal	0	7
217.	Black shale	0	6
218.	Black argillaceous limestone (*fossiliferous*)	1	4
219.	Brown limestone	3	2
220.	Brown shale	4	0
221.	Light gray concretionary limestone, imbedded in marl	13	0
222.	Gray marl and impure limestone, alternating	4	8
223.	Light gray marl	1	1
224.	Gray argillaceous limestone	0	5
225.	Green and gray marl	0	8
226.	Gray argillaceous limestone	1	4
227.	Brown shaly limestone	1	8
228.	Argillaceous limestone	0	3
229.	Brown marl	0	10
230.	Thick-bedded dark gray limestone	26	0
231.	Light gray marl, very soft	3	3
232.	Dark gray limestone	4	0
233.	Light gray marl, very soft	2	6
234.	Gray limestone	2	9
235.	Nodular gray marl	4	2
236.	Brown limestone	1	6
237.	Brown marl	0	2
238.	Brown limestone	0	10

		Ft.	In.
239.	Brown and black shale, with a band of limestone	0	10
240.	Brown limestone	3	0
241.	Not seen (supposed to be limestone and marl)	13	6
242.	Dark gray compact limestone	13	0
243.	Brown and black limestone	2	8
244.	Black shale	0	5
245.	Black nodular limestone	0	4
246.	Black compact limestone	0	4
247.	Not seen (thickness)	10	0
248.	Brown limestone, alternating with shale	3	0
249.	Gray limestone	0	8
250.	Black and brown shale	1	2
251.	Brown argillaceous limestone, impure	2	2
252.	Brown calcareous argillo-arenaceous shale	2	6
253.	Brown argillaceous limestone, impure	2	0
254.	Gray shale	0	7
255.	Gray argillaceous limestone, impure	1	0
256.	Shaly limestone	0	5
257.	Black limestone	1	1
258.	Black carbonaceous shale	0	2
259.	Black argillaceous limestone, fine-grained	0	5
260.	Black shale	0	1
261.	Dark gray limestone, nearly black	2	1
262.	Brown calcareous marl	0	6
263.	Brown argillaceous limestone	1	10
264.	Brown calcareous marl	0	7
265.	Black limestone, fine-grained	2	1
266.	Brown impure limestone, concretionary	1	7
267.	Gray limestone	0	7
268.	Brown shale	0	2
269.	Brown argillaceous limestone	2	0
270.	Brown shaly limestone	0	4
271.	Brown concretionary limestone	0	6
272.	Brown marl, with nodules of impure limestone	2	2
273.	Dark gray limestone	1	0
274.	Brown marl, with nodules of impure limestone	2	2
275.	Dark gray limestone	0	8
276.	Brown marl	0	5
277.	Dark gray limestone	0	8
278.	Marl parting	0	1
279.	Dark gray limestone	0	7
280.	Black marl	0	2
281.	Black limestone	1	1
282.	Brown limestone, alternating with marl and shale	1	6
283.	Dark gray limestone	1	9
284.	Black shale	0	1
285.	Gray limestone, weathering yellow	0	7
286.	Brown shale	1	7
287.	Marl, brown	0	3
288.	Brown argillaceous limestone	1	3
289.	Gray and brown compact limestone	5	6
290.	Gray concretionary marly limestone	1	9
291.	Yellowish argillaceous limestone	1	0
292.	Dark gray argillaceous shale	1	6

		Ft.	In.
293.	Light gray argillaceous limestone, impure	0	8
294.	Black and gray argillaceous concretionary limestone	4	0
295.	Ferruginous yellow marl	1	0
296.	Dark greenish-gray concretionary limestone, embedded in marl, irregular	15	4
297.	White and light gray oolitic limestone, *Encrinites*, *Corals*, *Spirifers*	167	0
298.	Greenish-brown limestone	13	0
299.	Gray and brown siliciferous limestone	12	10
300.	Dark gray limestone, with *Corals*	3	4
301.	Dark gray compact limestone, with *Corals*	9	10
302.	Ditto ditto *Corals*, *Spiriferæ*	24	0
303.	Light gray limestone, *Fossils*	16	0
304.	Dark gray limestone, *Fossils*	5	8
305.	Gray limestone, *Fossils*	6	0
306.	Black limestone, occasionally reddish	4	8
307.	Black limestone, occasionally reddish, *Encrinital*	21	0
308.	Gray and black limestone	11	0
309.	Black limestone	14	6
310.	Black and brown limestone	12	0
311.	Gray limestone	20	0
312.	Reddish compact limestone (*fossiliferous*)	30	0
313.	Gray and brown limestone	14	0
314.	Limestone, *highly fossiliferous*, *Spiriferæ*, *Corals*, *Productæ*	1	0
315.	Gray and red *fossiliferous* limestone	5	0
316.	Black limestone	3	0
317.	Red and brown limestone	5	0
318.	Black limestone	1	9
319.	Gray and red limestone	5	0
320.	Blackish and dark gray limestone	18	0
321.	Gray, red, and black limestone	2	6
322.	Gray and red limestone	22	0
323.	Gray limestone	16	6
324.	Light and dark gray limestone	17	2
325.	Ditto ditto thick-bedded	20	0
326.	Argillaceous limestone	10	0
327.	Dark compact limestone	1	6
328.	Light and dark gray argillaceous limestone, *Encrinital*	8	0
329.	Gray argillaceous limestone, *Spiriferæ*	17	0
330.	Black limestone	2	6
331.	Gray compact argillaceous limestone	9	0
332.	Light gray limestone	18	0
333.	Dark gray limestone, *Spiriferæ*, *Productæ*	16	0
334.	Red and gray limestone, *Fossils*	4	0
335.	Light and dark gray *fossiliferous* limestone	14	0
336.	Red and gray argillaceous shale	3	6
337.	Gray and red argillaceous limestone	5	6
338.	Impure shaly limestone	1	0
339.	Reddish gray limestone	7	0
340.	Light gray limestone (*Fossils*)	17	0
341.	Gray impure limestone	10	0
342.	Concretionary marl	1	6
343.	Gray limestone (*fossiliferous*)	4	1
344.	Gray impure limestone	3	3
345.	Dark gray limestone	5	0

	Ft.	In.
346. Light gray limestone	1	6
347. Dark gray compact limestone	10	6
348. Gray and brown limestone (*Fossils*)	0	2
349. Shale	2	0
350. Impure argillaceous limestone	1	9
351. Gray limestone	1	9
352. Impure marly gray limestone	4	0
353. Argillaceous limestone	1	0
354. Shaly limestone	0	8
355. Impure argillaceous limestone	1	6
356. Light gray limestone (*Fossils*)	1	10
357. Impure gray marly limestone	1	5
358. Siliciferous limestone	6	0
359. Marly limestone	1	6
360. Light gray compact limestone	16	6
361. Light gray marly limestone	4	3
362. Light and dark gray compact limestone	12	0
363. Gray argillaceous limestone, *Spiriferæ, Productæ, Encrinites*	9	0
364. Red shaly limestone, *Spiriferæ, Productæ, Encrinites*	1	4
365. Red argillaceous limestone	1	10
366. Gray marly concretionary limestone	2	6
367. Dark gray reddish limestone, *Spiriferæ, Productæ*	4	7
368. Light gray limestone, *Productæ* and *Spiriferæ*	2	2
369. Limestone and marl alternating, *Spiriferæ*, and *Productæ abundant*	4	0
370. Light gray limestone, coarse-grained, *Fossils*	2	0
371. Concretionary marl and shale, *Spiriferæ*	2	2
372. Gray and reddish limestone, *highly fossiliferous, Spiriferæ, Productæ,* and *Encrinites*	5	6
373. Marly limestone, *Spiriferæ and Productæ*	0	6
374. Red and gray *fossiliferous* limestone	2	6
375. Brown shale	0	8
376. Dark gray limestone, *Fossils*	0	11
377. Brown shale	0	4
378. Brown limestone	0	8
379. Brown shale	0	2
380. Brown limestone	0	2
381. Brown shale	0	11
382. Brown limestone	1	6
383. Brown shale	0	6
384. Brown and gray limestone, *Fossils*	0	9
385. Brown shale	0	5
386. Brown and gray limestone	1	4
387. Brown shale	0	5
388. Brown limestone (*fossiliferous*), with two inches of shale	1	5
389. Brown shale, with thin beds of limestone	1	2
390. Gray and brown limestone	1	6
391. Brown shale	0	2
392. Brown limestone	0	0½
393. Brown shale	0	2
394. Brown limestone	0	5
395. Brown shale	0	4
396. Brown limestone	0	3
397. Brown shale	0	2
398. Brown limestone	0	6

	Ft.	In.
399. Brown shale	0	2
400. Ground not seen (supposed to be alternations of limestone and shale)	24	6
401. Brown shale and limestone, alternating	1	6
402. Brown shale	0	7
403. Brown and blue limestone	0	5
404. Brown shale and limestone, alternating	0	5
405. Brown limestone	0	7
406. Brown and gray limestone	0	2
407. Brown limestone and shale, alternating	0	10
408. Brown and gray limestone.	0	7
409. Brown shale	0	3
410. Brown and gray limestone.	0	5
411. Brown shale	0	4
412. Gray and brown shale and limestone, alternating	1	0
413. Brown and gray limestone.	0	7
414. Brown shale	0	6
415. Gray limestone	0	4
416. Brown shale	0	9
417. Gray limestone (*Spiriferæ*)	0	3
418. Brown shale and limestone, alternating	1	4
419. Not seen. (The bone bed is in this part of the section*).	5	0
420. Coarse red limestone	5	0
421. Dark red limestone, fine-grained.	2	4
422. Red marly shale	0	2
423. Red and brown limestone	1	10
424. Red marl	0	1
425. Red limestone	3	6
426. Red and green marl	0	4
427. Reddish gray limestone	1	1
428. Dark brown greenish marl, with three thin bands of limestone	1	2
429. Red and gray limestone, a cômpact bed	3	6
430. Limestone, marl, and shale, alternating	4	0
431. Brown marl	0	9
432. Siliciferous limestone	0	6
433. Green and red marl and arenaceous shale, alternating	1	6
434. Brown and grayish green argillo-arenaceous shale	5	6
435. Siliciferous limestone	0	4
436. Brown shale	1	6
437. Siliciferous limestone	1	0
438. Argillaceous shale	2	0
439. Argillo-arenaceous shale	1	10
440. Siliciferous limestone, with partings of shale, irregular	1	3
441. Argillaceous shale	0	4
442. Greenish-gray and red marl	1	0
443. Gray limestone, slightly siliceous	4	6
444. Brown and red marl.	2	0
445. Greenish-gray marl	1	5
446. Siliciferous limestone, with eight shale partings	1	11
447. Brown marl	1	0
448. Greenish-gray limestone	0	6
449. Brown marl	0	7
450. Limestone	0	1

* A bed containing an abundance of fish-palates, with other fish-bones, occasionally

		Ft.	In.
451.	Brown marl	0	5
452.	Impure gray limestone (*Terebratulæ, Encrinites*)	2	0
453.	Gray marl	1	0
454.	Impure gray limestone	0	1
455.	Gray marl	0	11
456.	Very hard black argillaceous limestone	0	9
457.	Calcareous shaly marl	0	9
458.	Gray limestone, impure	0	6
459.	Shale, with bands of impure limestone	0	8
460.	Impure gray limestone	2	5
461.	Brown marl	0	5
462.	Impure limestone	0	5
463.	Dark gray and brown limestone, with partings of shale	2	3
464.	Gray and brown limestone	1	0
465.	Brown shale	0	3
466.	Gray and brown limessone	0	6
467.	Gray shale	1	11
468.	Impure limestone	0	5
469.	Brown shale	1	0
470.	Impure limestone	0	3
471.	Yellow marl	1	10
472.	Impure limestone	0	10
473.	Brown shale	0	2
474.	Impure limestone	0	3
475.	Brown shale	0	1
476.	Impure limestone	0	2
477.	Brown shale	0	3
478.	Impure limestone	1	7
479.	Yellow marl	0	4
480.	Impure limestone	1	2
481.	Marl	0	1
482.	Impure limestone	0	2
483.	Brown and greenish marl	2	6
484.	Yellow sand	0	9
485.	Greenish marl	0	3
486.	Impure limestone	0	1
487.	Yellow sandy marl	0	3
488.	Impure limestone; brown and shaly marl	0	9
489.	Dark greenish shale	1	10
	Old Red Sandstone.		
490.	Gray arenaceous shale	2	0
491.	Red marl	2	8
492.	Gray arenaceous shale, micaceous	5	0
493.	Red and gray marl	8	6
494.	Sandstone	0	5
495.	Gray and red marl	3	8
496.	Soft gray marl	2	6
497.	Red and green marl	2	2
498.	Light gray quartzose sandstone	3	0
499.	Red and green marl	1	0
500.	Quartzose conglomerate	3	9
501.	Purple and green marl	0	6
502.	Light gray quartzose conglomerate	1	0
503.	Red and white conglomerate	1	6

	Ft.	In.
504. Dark gray ferruginous sandstone, soft and micaceous	3	4
505. Quartzose sandstone, with thin partings of marl, irregular	7	0
506. Light gray quartzose sandstone	5	4
507. Red marl	0	3
508. Hard red sandstone	1	2
509. Red marl, indurated and irregular	4	0
510. Gray and red sandstone, irregularly bedded	24	0
511. Red sandstone, micaceous	1	0
512. Indurated yellow marl	2	8
513. Dark gray micaceous sandstone	3	4
514. Dark brown indurated marl	1	6
515. Red sandstone	5	0
516. Gray and purple marl	1	0
517. Red and brown sandstone, soft and irregular	2	4
518. Purple marl	1	0
519. Soft sandstone	0	6
520. Gray and red marl, micaceous	18	0
521. Red and green marl, micaceous	5	0
522. Soft sandstone, quartzose	1	7
523. Red and green sandy marl	2	0
524. Light gray quartzose sandstone	12	0
525. Brown ferruginous arenaceous shale	7	9
526. Soft micaceous sandstone	1	6
527. Brown marl	1	6
528. Brown and gray soft sandstone	7	0
529. Red and green marl	4	5
530. Red marl	9	0
531. Light gray sandstone	0	4
532. Dark purple and greenish sandy marl, micaceous	8	0
533. Gray quartzose sandstone, irregularly bedded, and micaceous	30	0
534. Purple marl, with stripes of green marl, irregular	8	0
535. Light gray quartzose sandstone	26	0
536. Red and green marl	6	0
537. Light red and gray soft sandstone	9	10
538. Reddish gray micaceous sandstone	29	0
539. Yellow sandy marl	1	0
540. Gray sandstone, quartzose and micaceous, with nine inches of quartz-pebbles at the bottom	4	10
541. Red marl	2	8
542. Red quartzose sandstone	9	10
543. Red micaceous marl	4	8
544. Gray micaceous sandstone	6	9
545. Red marl	0	10
546. Red sandstone	4	4
547. Red marl	3	0
548. Red sandstone	4	0
549. Red and green marl	7	0
550. Red and gray sandstone	4	0
551. Red marl, with thin bands of red sandstone	10	0
552. Red marl, with thin bands of gray sandstone	7	0
553. Gray quartzose sandstone	7	0
554. Red concretionary marl	1	4
555. Red sandstone	1	4
556. Red and green concretionary marl	2	4

	Ft.	In.
557. Red sandstone	2	4
558. Red and gray sandstone, micaceous	14	0
559. Red marl	9	0
560. Gray and red sandstone, quartzose and hard	2	6
561. Red marl	15	0
562. Sandstone	0	6
563. Red marl	2	10
564. Red sandstone	0	10
565. Red marl	1	9
566. Red sandstone	0	4
567. Red marl, with green specks	2	0
568. Red sandstone	4	8
569. Red marl	13	0
570. Red sandstone	1	11
571. Gray sandstone, quartzose and micaceous	3	0
572. Micaceous red marl	4	10
573. Red and gray sandstone, hard and micaceous	4	0
574. Red concretionary marl, irregular	6	0
575. Red sandstone, very irregular	1	0
576. Soft red sandstone, with bands of hard gray sandstone	5	7
577. Gray sandstone, quartzose and hard	10	6
578. Soft red sandstone	3	6
579. Hard red sandstone	1	3
580. Micaceous red marl	9	6
581. Gray conglomerate, with rounded quartz pebbles	8	0
582. Red marl	0	8
583. Quartz conglomerate	10	0
584. Ground not seen	70	0
585. Sandstone and marl, alternating	10	0
586. Marl and thin beds of marly sandstone	80	0
587. Sandstone, red and gray	100	0

Of the 587 divisions noticed in this section, the lower 97, referred to the upper part of the old red sandstone, correspond, generally, with similar portions of the same rock in Herefordshire, Monmouthshire, and South Wales. Of the 2,338 feet, referred to the mountain limestone, we may take about 500 feet for that alternation of shales and limestones, frequently argillaceous, which has been termed Lower Limestone Shale. Towards the lower part of these beds, there is an accumulation of fish-bones, sometimes water-worn, with an abundance of fish-palates, known as the bone-bed. It is not well exposed in the left bank of the Avon, along which this part of the section was taken, but is readily seen on the right bank, and from it multitudes of the palates have been at different times obtained. This bone-bed, which marks a sea bottom, on which the hard parts of fish remains were collected together, as they now are, under favourable conditions, agrees with similar accumulations in the same part of the general series of these beds, previously noticed. It shows that over a wide area similar conditions prevailed; here and there patches of sea bottoms being covered by fish remains, which could not be digested or readily eaten,

the droppings of fish being mingled with them in some localities. There are some arenaceous beds with plants, apparently, amid the ground not well seen (No. 400), which are interesting from their position, especially when taken in connexion with those previously noticed at the base of the carboniferous or commencement of the old red sandstone elsewhere; as also with those noticed by Dr. Bright, in the upper part of the latter rock in his description of this Avon section.* Among the fossils in these lower beds, Spiriferæ are very common; and the Leptæna, which varies so much, even in the same bed, and which has by some been regarded as a variety, modified by conditions, of the *Leptæna depressa*, is a marked shell, as it is elsewhere in the lower part of the carboniferous limestone in Somersetshire and Gloucestershire, and in South Wales.† Encrinites are also often very abundant.

Above this accumulation of mud and calcareous matter, solid limestone beds succeed in considerable thickness. In them encrinites are often common, and many fish-palates are detected in particular beds. There was then an interruption of conditions, and much mud and marly matter became intermingled with the calcareous accumulations. After a time the calcareous conditions again prevailed, and limestones are found to have been formed in thick beds. Some of the coral beds in these upper accumulations are extremely interesting, from the resemblance they bear to coral reefs, a circumstance which has not escaped Mr. S. Stutchbury,‡ to whom the Geological Survey is indebted for much valuable information and assistance afforded while investigating the vicinity of Bristol.

The upper part of the series is characterised by an admixture of sandstones and shales with the calcareous beds, the commencement of that great change of conditions which produced the accumulation of the superincumbent coal measures. From time to time sand and mud drifts covered the limestones, which in some cases exhibit a mixture of mechanically-formed parts; as, for instance, No. 97, where quartz pebbles are dispersed through an oolitic limestone, the origin of the oolitic grains of which may also be so far mechanical, that the calcareous matter enveloped a minute nucleus, while gentle motion was kept up.§ Oolitic limestone is not uncommon in this upper part of the series, as well in the Mendip Hills and other parts of Somerset and Gloucestershire, as in the Avon section. This character is, however,

* Geol. Trans., First Series, vol. iv. p. 201.

† The same shell is common in the lower part of the carboniferous series in the south-east of Ireland.

‡ West of England Journal of Science and Literature, p. 45, &c.

§ Quartz pebbles are also noticed as occurring at the top of the oolitic limestones, Nos. 104 and 109.

not confined to the upper series, since it may be found, especially in the Mendip Hills, among the lower beds (as for example, near Frome), though it is more rare in the latter. Often, certainly, these oolitic limestones, though hard and compact, have the appearance of the kind of mechanical origin above noticed; while at others this manner of accounting for their appearance is more doubtful. It will be observed, that in the detailed section of the Avon rocks, the oolitic limestones are much mingled with detrital beds, such as sandstones and shales, the former of which, at least, required a fair movement of water to transport the sands of which they are composed.

The carbonaceous bed, in which we find grains of coal, No. 90, with its subjacent underclay, containing *Stigmaria ficoides*, an assemblage to be noticed under the head of Coal Measures, is interesting as showing the commencement of those conditions in the south of England which produced coal, such conditions having prevailed at an earlier period among the carboniferous limestone accumulations in the North.

The sandstones interstratified with the upper limestones, as indeed many of the marls and shales, are coloured red by peroxide of iron, so that this substance was intermingled with the drift of the time, assuming the iron to have been in its present state, as does not appear improbable. Gradually the calcareous matter disappeared, the drifts of sand and mud prevailed, and finally, there was a very thick accumulation of sand.

The carboniferous limestone in other directions near Bristol, including the boundary of this series, where not concealed by more modern deposits, round the coal field which occurs in that neighbourhood, and extending towards Tortworth, presents the same general character with the Avon section. And we are here anxious to acknowledge the great assistance the Geological Society has derived from the labours of Mr. William Sanders, of Bristol, who most handsomely placed at the disposal of the Survey his beautiful maps of the country bounded by the Severn and Bristol Channel from Purton Passage to Clifden, and thence inland by Chipping Sodbury, in one direction, and by Keynsham and Newton on the other, to the Week rocks, a large area, and containing very complicated ground.*

* These maps are now incorporated with those of the Survey, Mr. Sanders having completed them for the purpose, with the exception of the coal measures, which were examined and mapped by Mr. David Williams, of the Survey, who also examined many portions of the adjacent county. The area embraces a most interesting country, and was worked out upon a six-inch enlargement of the Ordnance Survey with the utmost attention to accuracy. As the one-inch scale of the Geological Survey Maps does not fully exhibit some of the more complicated detail, it is to be hoped that Mr. Sanders will publish a map of the Bristol country upon, at least, a scale of two inches to the mile, which would be generally sufficient for the purpose.

Some portions of the carboniferous limestone near Bristol, as has been noticed by Dr. Buckland and Mr. Conybeare,* contain much carbonate of magnesia, so that beds in it closely resemble some of the dolomitic or magnesian limestones of a more recent date in the same vicinity. This character, which seems very local, may be well seen at Kingsweston and in the vicinity of Portishead.

The general character of the carboniferous limestone of the Mendip Hills is much the same as at Bristol;† the lower shales present similar characters, the lower limestones are replete with encrinites, often shown, when weathered, to constitute the greater part of numerous beds, and the upper beds are often oolitic, corals being far more abundant in the latter than in the lower beds. There is more chert observable in the lower part of the Mendip beds, and sometimes this substance is abundant in them. A very good section of the western part of the series, with the exception of the passage-beds into the coal measures, may be seen by ascending Vallis Vale, near Frome, and by proceeding along Murder Combe towards the old red sandstone axis near Whatley, on the south-west. On the west the sections of the lower beds, which would be so valuable as respects the Devonian rocks, are in a great measure concealed by the overspread of dolomitic limestone and conglomerate in the direction of Shipham.

Quitting the Mendip exposure of the carboniferous rocks, it will be desirable to pass to Dean Forest to observe the general character and thickness of this series in that direction, where, however, we have to contend with the disposition of the coal measures to overlap, and thus afford an imperfect section of the series.‡ The following section, by Mr. David Williams, is probably free from this objection, as the upper deposits of the limestone series would appear to pass, by alternations, into the lower beds of the coal measures.

Section of Carboniferous Limestone and upper beds of Old Red Sandstone near Lower Purlieu, Forest of Dean, Gloucestershire.

	Ft.	In.
1. Gray sandstone	8	0
2. Marl	1	4
3. Sandstone	32	0
1 to 3 Lower part of the Coal Measure Series, commonly termed Millstone Grit.		
4. Gray and red impure and sandy limestone	8	0

* Observation on the South Western Coal District of England, Geol. Trans., Second Series, vol. i. p. 291.

† For the mode of occurrence of the carboniferous limestone of the Mendip Hills, see Horizontal Sections of the Geological Survey of Great Britain, sheet 15, section 1; sheet 16, sections 1, 2, 3, and sheet 17, section 1.

‡ For sections across the Forest of Dean, see Horizontal Sections of the Geological Survey of Great Britain, sheet 12, section 1, and sheet 15, section 2.

	Ft.	In.
5. Marl	0	6
6. Gray impure and sandy limestone	13	0
7. Marl	0	8
8. Impure limestone	3	0
9. Marl	1	0
10. Red sandstone, with calcareous matter	9	0
11. Marl	0	8
12. Gray and red sandstone	21	0
13. Sandstone, with interstratified beds of shale	37	0
14. Red and soft sandstone	20	0
15. Soft sandstone, with thin beds of shale	20	0
16. Hard sandstone	19	0
17. Sandstone, red, and with hematite veins	49	0
18. White, gray, and red limestone	90	0
19. Limestone, with intermingled hematite, extensively worked	60	0
20. Gray, white, and blue compact limestones	330	0
21. Shale and limestone alternating	107	0
22. Gray argillaceous limestone	2	0
23. Gray shale	0	6
24. Gray limestone	1	6
25. Shale	0	8
26. Limestone	1	10
27. Gray shale, with thin bands of limestone	10	0
28. Argillaceous limestone	1	0
29. Shale with thin bands of limestone	1	0
30. Argillaceous limestone	1	2
31. Shale and limestone alternating	2	8
32. Limestone	1	1
33. Shale	0	8
34. Limestone	0	4
35. Soft black shale	0	6
36. Limestone	1	6
37. Limestone and shale	2	0
38. Shale	0	6
39. Limestone	0	9
40. Shale	0	6
41. Limestone	2	0
42. Black shale	0	6
43. Limestone	2	8
44. Black shale	0	6
45. Brown limestone, with shale partings	4	8
46. Dark shale	1	0
47. Limestone	3	0
48. Shale	2	0
49. Limestone	0	8
50. Arenaceous shale	1	6
51. Limestone	1	7
52. Sandy marl	0	6
53. Limestone	4	0
54. Dark shale	1	0
55. Limestone	2	0
(End of the Limestone series.)		
56. Soft yellow sand, with bands of yellow sandstone	22	0
57. Light gray sandstone, with marl partings	12	0

	Ft.	In.
58. Gray marl, with bands of sandstone, 3 inches thick	10	0
59. Gray sandstone	3	0
60. Gray sandstone alternating with soft marl	8	0
61. Gray sandstone with few pebbles of quartz	14	0
62. Red marl, with green marl partings	17	0
63. Gray soft sandstone	22	0
64. Gray sandstone, with a few pebbles of quartz	6	0
65. Red and gray micaceous sandstone	6	0
66. Soft gray micaceous sandstone	29	0
67. Red, gray, and claret-coloured marl	14	0
68. Thick and thin-bedded gray sandstone	18	0
69. Gray micaceous sandstone	6	0
70. Thick and thin-bedded gray sandstone	11	0
71. Sandstone and conglomerate	9	0
72. Green marl	0	6
73. Gray sandstone	6	6
74. Green marl	0	10
75. White and gray sandstone	7	6
76. Gray sandstone, marly at top	1	10
77. Gray sandstone	11	0
78. Green marl	3	0
79. Gray sandstone, with green marl partings	22	0
80. Green sandstone	2	0
81. Gray and green marl	1	0
82. Gray sandstone	4	0
83. Gray sandstone, with a few quartz pebbles	7	6
84. Red marl	2	6
85. Red and gray sandstone	4	6
86. Gray sandstone	4	2
87. Green and red sandstone, with shale alternating	16	0
88. Red sandstone, with a few quartz pebbles	20	0
89. Sandstone, with marl partings	42	0
90. Gray sandstone, with a few quartz pebbles	4	0
91. Green marl	2	4
92. Red sandstone and conglomerate	1	10
93. Red and green marl	8	0
94. Red and white sandstone	10	0
95. Soft red sandstone	4	0
96. Green and red marl	13	6
97. Gray sandstone	4	0
98. Red marl	2	6
99. Green and red marl	1	0
100. Red and gray sandstone, with red shale partings	2	0
101. Red and white sandstone and conglomerate	46	0

From this section we learn that the total thickness of 2338 feet obtained on the Avon has diminished down to 791 feet; that the lower shales, about 500 feet thick near Bristol, are about 165 feet deep at Dean Forest; and that the upper mixture of sandstones, marls, and limestones of the Avon, 400 feet thick, is represented at Purlieu, by sandstones, limestones, and marls, 146 feet in thickness. Thus the central portion of the carboniferous series, 1438 feet in depth at Bristol, becomes 480 feet at Dean Forest. The lower beds are diminished to

about one-third, the central portion the same, and the upper beds very nearly in the same proportion. A somewhat remarkable instance of the diminished effects of similar general causes in the same ratio for the different chief parts of this series in the two localities.

The Dean Forest section presents us with an interesting local accumulation of peroxide of iron intermingled with the calcareous deposits of the time; so that we should regard the ironas having constituted as much a portion of the rocks, in a particular part of the general series, as any other marked beds. It has long been extensively worked, so that its mode of occurrence is well understood. It ranges in variable quantities, but always in its relative geological position, cropping out round the basin-formed mass into which the beds of Dean Forest have been forced. Though hematite iron ore is known elsewhere among the carboniferous rocks of south-western England and South Wales, in some localities having been raised in large quantities, it has hitherto, in them, been only detected in veins, cutting the beds like numerous other mineral veins, with the exception, perhaps, of the hematite ore raised from the carboniferous limestone for the Pentyrch iron works north of Cardiff, the position of which is somewhat equivocal. Although, in endeavouring to account for the position of the iron ore in the carboniferous limestone of Dean Forest, we may, from existing knowledge, be led to suppose that it was formed in the sea, amid the marine accumulations with which it is associated, so that it may not have been a bog iron ore of that geological period, still its dispersion at the same time over so wide an area would induce us to infer that the peroxide was thrown down from water in which the iron had previously been, in some soluble form, spread over the space required.

The contortions and denudations of the older rocks have been such, that the carboniferous limestone of Dean Forest becomes separated by the uprise of subjacent rocks, and by denudation, from the limestones which skirt so large a portion of the Monmouthshire and South Welsh coal field, though continued in a long line of country, and supported by the old red sandstone from the southern part of the forest, across the Wye, where it produces such beautiful scenery, to Penhow and other adjacent places in Monmouthshire.

After the exposure of the carboniferous limestone along the edge of this coal district, from Pontypool to the vicinity of Llantrissant, it becomes covered up by dolomitic conglomerate, new red marls, and lias in such a manner that the sections are not readily seen, more especially as the limestone is rolled into an arch, accompanied by minor flexures (as noticed by Dr. Buckland and Mr. Conybeare *) beneath this cover-

* Observations on the South-western Coal Districts of England, Geological Transactions, Second Series, vol. i. p. 217.

ing of more modern accumulations. There would appear, as we might anticipate, a continued thickening of the general mass of the limestone series towards the west. At Swansea we have an opportunity of observing the section, and, though much disturbed, we may take the total thickness at 1500 feet.

Proceeding from Pontypool round by the northern range of the carboniferous limestone, to Caermarthen Bay on the west, we find a considerable diminution in the general thickness of the mass, preparing us for its final disappearance in the further continuation of the same range of beds in Pembrokeshire. The depth of the limestone at Pen y rhiw on the south of Llangadock,* is 510 feet, and in this and neighbouring sections we see that the lower shales, so conspicuous in the range of the limestones on the south of the South Welsh and Monmouthshire coal district, and in Gloucestershire and Somerset, have dwindled away, so as to be only a few feet in depth, scarcely discernible except on well-exposed mountain sides, or in the ravines.

If we, in imagination, strip off the superincumbent rocks, coal measures included, flatten out the beds, and restore the portions carried away by denudation at various geological times, so as to endeavour to form some conception of the condition of the mass of the carboniferous limestone immediately after its formation, we perceive that the various sections obtained in different parts of the general area would justify us in concluding that the total thickness of the whole did not much exceed 2500 feet, under the most favourable conditions, in any one place. This thickness, with minor variations, seems to have continued in a direction from South Pembrokeshire to the vicinity of Bristol and the Mendip Hills. On the north of the western part this considerable thickness diminished within a few miles, so that we have no reason to suppose the boundary of the deposit extended beyond the distance of Haverfordwest in that direction. We have evidence that the limestones, in like manner, became less thick from south to north along the whole distance from Haverfordwest to Pontypool (83 miles). We may safely infer that the boundary observed at Haverfordwest was continued northward of the present line of carboniferous limestone, but at no great distance, judging from the rate of diminished thickness observed between the southern and northern outcrop of the carboniferous limestone. Fortunately a portion of this extension on the north, now cut away by denudation, remains on the summit of Pen carreg calch, resting on old red sandstone, and covered by the lowest beds of the coal measures; and we here again observe the rate at which the thickness of the limestones is diminishing northward.

* For a section across this country, see Horizontal Sections of the Geological Survey of Great Britain, sheet 3, section 2.

Continuing towards Ross and Newent, we again appear to have evidence of an original boundary of the limestones in that direction. We have no reason to conclude that there was any destruction of the carboniferous limestone anterior to the formation of the coal measures towards Newent, so that when near that town we find the latter rock reposing directly on the old red sandstone, we may fairly infer that the carboniferous limestones did not, when these beds of the coal measures were accumulating, extend so far in that direction. This opinion receives support from the fact that at Howl Hill, near Ross, the lowest beds of the coal measures, those commonly considered as equivalent to the millstone grit of the central and northern parts of England, rest directly on the lower shales of the carboniferous limestone, having overlapped the higher beds, so that probably the original boundary of the limestones was continued between Newent and Ross. It would be out of place to endeavour to trace the original boundary line of the carboniferous limestone further, and in a northern direction,* against the older deposits. Taken in connexion with Ireland, the subject of the original boundaries of this great body of calcareous matter is one of great geological interest, more especially when viewed in connexion with the probable conditions of the production of so large accumulation of carbonate of lime, much of which appears to have constituted the hard parts of marine animals.

In the direction of Dean Forest the lower shales and limestones, though not so deep as near Bristol, still show the accumulations of mud and calcareous matter in fair quantity in that part of the area, and judging from the overlap of the coal measures at Howl Hill, the more solid beds did not there extend so far towards the boundary line. This, however, was not the state of things to the westward, where the more solid beds overspread the shales, as if a deeper part of the sea on the south had been gradually filled up with mud, some calcareous matter, and thick accumulations of animal remains (among which the broken columns and other portions of encrinites were abundant), and that subsequently there had been a more general spread of beds, among which corals were often abundant, extending to the northern boundary of the whole accumulation in more moderate depths.

Upon the hypothesis of deeper water in the direction of Devonshire, we may be prepared to find, not only a large quantity of mud capable of being thrown down in it, equivalent to the lower shales of the limestones above noticed, but also conditions unfavourable to the formation of the limestones themselves; so that while very little common detritus

* As the carboniferous limestone appears to overlap the old red sandstone on the east side of Dean Forest, near Blakeney, its original boundary line may have been much curved in that locality.

was mingled with the latter in the north and north-west, it was abundantly accumulated on the south and south-west, thus constituting common detrital equivalents to the limestones. As the whole thickness of the carboniferous limestones disappears between the south coast of Pembrokeshire and Haverfordwest, there would be nothing remarkable in the disappearance of an equal thickness of the same limestones between the Mendip Hills and the Quantock Hills. The facts, however, above mentioned respecting the character of the Pilton group, would lead us to suppose that we there possessed the equivalents of, at least, the lower carboniferous limestone shales of the north and north-west.

Before, however, we proceed to notice the Devonian rocks further, those which have been considered as some equivalent of the carboniferous limestones in other parts of England, it is desirable to mention certain beds which occur above the carboniferous limestone near Swansea (if, indeed, they may not, in a great measure, be considered as an upper portion of it), since there is a certain general resemblance between them and the beds in Devonshire immediately above the Pilton group. Where these beds reach the coast in Swansea on the east, the section exposed is not good, and the beds are also concealed where the coast line cuts them towards Caermarthen Bay in the west; but, fortunately, they can be well studied along the course of the river near Bishopston, and the following section, in descending order, is there obtained.

Section at Bishopston, Gower, above the Carboniferous Limestone.

	Ft.	In.
1. Black shale, with impure ironstone nodules	511	0
2. Black shale, with large nodules of ditto	15	0
3. Black shale	180	0
4. Dark limestone	0	4
5. Black shale	60	0
6. Sandstone	0	8
7. Black shale	7	0
8. Sandstone	0	10
9. Black shale, with a sandstone bed	23	0
10. Fine grained dark gray sandstones, 2 to 10 inches thick, alternating with black shale	12	0
11. Black shale, with dispersed nodules of impure ironstone. Seams and nodules more abundant in the lower 5 feet	129	0
12. Nodules of ironstone, in a line		
13. Black shale, with seams and nodules of impure ironstone	92	0
14. Dark-coloured shale, with beds of fine-grained dark sandstone, from 1 to 6 inches thick; also some arenaceous shale	49	0
15. Black shale, with some fine arenaceous concretions	43	0
16. Fine flinty slate	1	0
17. Black shale, with a few interstratified fine-grained arenaceous beds	26	0
18. Black shale, with coarser arenaceous beds	151	0
19. Black arenaceous shale	36	0

	Ft.	In.
20. Slaty fine-grained sandstone, some beds 2 and 3 inches thick, gray and brown	75	0
21. Black flinty slate, some beds 2 and 3 inches thick	51	0
22. Black shale	129	0
23. Gray shale, with black flinty beds, ferruginous from decomposition of the latter	30	0
24. Light yellowish gray marl, with some harder beds, containing *Encrinites*, *Spiriferæ*, &c.	15	0
25. Gray compact limestone, *Carboniferous Limestone*		

Though gray compact limestone is seen to support the series of deposits noticed in this section near Bishopston, within a few miles, near Oystermouth Castle, on the east, a dark-coloured carbonaceous limestone much intermingled with siliceous matter, the most impure limestone in the higher part, is observed to form the upper portion of the carboniferous limestone of the Mumbles. Its thickness seems confined to a few feet, and parts of it are highly fossiliferous. The same kind of limestone would appear to occur, judging from imperfect sections, here and there along the boundary line of the carboniferous limestone between Swansea and Caermarthen bays.

Although much covered up by more modern accumulations on the eastward of Swansea, there is enough of the general section of the coal measures and carboniferous limestone obtained in that direction to show that the Bishopston beds are but slightly developed eastward, though about 1600 feet in the Gower section. At Tenby, on the west, we recognise the continuation of these beds, though but a few feet thick, in the carbonaceous shales, with nodules and irregular seams of dark argillaceous limestone (containing Goniatites) and the hard sandstones, which there really succeed the carboniferous limestone in ascending order, though the contortions have been such, that beneath the town, where this part of the series is well exposed, these beds have the deceptive appearance of dipping under the limestones.* In Gower, therefore, we would appear to possess the principal section of a kind of lenticular mass, which fines off to the east and west, and is interposed between the carboniferous limestone and the ordinary coal measures. It may not be separable, at least in part, from those sandstones and conglomerates, frequently very hard (to be noticed hereafter), which support the ordinary coal measures, and repose on the carboniferous limestone throughout a large portion of the district; but, at least, this accumulation was formed under minor conditions, differing from those which produced the sandstones and conglomerates, since the results have been, with some slight exceptions, so different.†

* Horizontal Sections of the Geological Survey of Great Britain, Sheet 2, No. 1.

† In some parts of Gower, wavellite has been detected by Mr. Logan, among the hard siliceous beds of this series.

If we cross the Bristol Channel to North Devon, and examine the series of beds which immediately succeeds the Pilton group, we are soon struck with the general resemblance it bears to the Gower series. As elsewhere * stated, there is great difficulty in drawing a good boundary line between the Pilton group and these beds, there being an apparent passage between them; that is, the change of conditions under which both were formed has been gradual, even amounting to minor alternations. At Fremington Pill, near Barnstaple, one of the best of the natural sections obtained, calcareo-argillaceous slates, with fossiliferous seams, containing Corals, Encrinites, Productæ, Spiriferæ, &c., are succeeded, in the ascending order, by slates containing nodules of gray limestone, and seams of the same fossils. Gradually the slates become intermingled with sandstones, the latter finally constituting thick beds and the alternating slates acquiring a different character, here and there carbonaceous matter being disseminated in them. The somewhat calcareous mud of the highest part of the Pilton group, with its layers of animal remains, became gradually intermixed with sand, the latter increasing by degrees, perhaps from increased facilities of transport by water, as the sea bottom was filled up by the mud, as now happens, (p. 8), or was otherwise raised, and finally carbonaceous matter, probably derived from decayed plants, became mixed with the mud associated by alternations with the sand deposits.

By further examination southward to Muddlebridge, the carbonaceous part is seen greatly to increase, so that black carbonaceous slates succeed the beds above mentioned, and with them black limestones are found associated.† Here then we have a marked change, and the accumulations of the time are characterised by the dissemination of carbonaceous matter. We should anticipate that this change would be accompanied by a change or modification of the animals which lived in or upon the sea and sea-bottom previously, and that we should discover animals which had been suited to the new carbonaceous conditions, those appearing to whom the back mud would not be distasteful or injurious; and, accordingly, we find Posidoniæ, creatures which were apparently suited to carbonaceous mud, judging from the abundance of their remains in situations where they appear to have lived in multitudes. Following the range of these beds eastward, along the boundary of the Pilton group for about 36 miles, there would appear some minor variations, and a certain general change as regards the limestones. At Coddon Hill, Professor Phillips notices whitish, gray, and black shales, in thin beds, intermingled with white arenaceous and argillaceous layers, as resting on the black shales and limestones of

* Report on the Geology of Cornwall, Devon, and West Somerset, p. 102.

† A detailed section of this ground will be seen, Report, &c., plate 3, fig. 1.

Swimbridge and Venn, the laminated layers containing Goniatites, Orthoceratites, Terebratulæ, and Posidoniæ. These sandstones are the Coddon Hill Grits of the Rev. David Williams.*

There is a good section of the apparent passage of the Pilton group into these beds near Bampton.† Argillaceous slates, with fossiliferous seams, as near Fremington, and some carbonate of lime gradually acquire carbonaceous matter, and pass into a hard and somewhat arenaceous rock. There were then alternating banks of mud, commonly carbonaceous, and of sand, producing black shales and sandstones. After a time dark carbonaceous limestones were formed, and, subsequently, above them, with some intervening mud and sand, limestones, partly gray and partly black, with shales, Posidoniæ being found amid the latter. At Westleigh, still further east, where the new red sandstone series covers up and conceals the range of the North Devonian rocks in that direction, the limestones of this date would appear to have lost their admixture of carbonaceous matter, as if, as elsewhere remarked, the distribution of such matter, probably derived from plants, was not so extensive in this part of the sea-bottom, and its absence was favourable to the continued existence, in that direction, of the animals, the remains of which were entombed in the lower series.‡ Professor Phillips notices in the Westleigh limestones, part of which is crinoidal, *Spirifera lineata*, *Leptæna Martini ?* and *Acroculia ?* He also mentions many thin laminated beds of white and flesh-coloured shale on the southern slope of Westleigh Hill, full of several species of Goniatites (*G. mixolobus*, *G. spirorbis*), a few Posidoniæ (*P. Becheri*), a Brachiopod (*Orthis Hardrensis*), and several plants.§ The *Posidonia Becheri* seems to range along the whole line from Muddlebridge to Westleigh, *P. tuberculata* being also found at Venn and Swimbridge, and *P. lateralis* at Venn. The other organic remains noticed by Professor Phillips in these beds are, *Turbinolopsis pauciradialis* (near Tawstock), *Cyathocrinus distans* (Coddon Hill), *Pleurorynchus minax* (Halberton), *Leptæna mesoloba* and *Atrypa insperata* (Coddon Hill), *Orthoceras cylindraceum* (Swimbridge), *Goniatites spiralis* (Bampton), *G. crenistria* (Swimbridge), and *G. mixolobus* (Bampton and Coddon Hill).

Proceeding to the south of the carbonaceous rocks, where the upper

* In the cherty grit beds of this part of the series, wavellite has long been known, and without venturing to lay much stress upon this fact, it may be regarded as interesting to have found the same mineral under similar lithological, and supposed similar geological conditions, both in Gower and Devonshire. It usually fills the joints of the beds among which it is found.

† Report, &c., plate iii. fig 3.

‡ Report, &c., p. 105.

§ Figures and Descriptions of the Palæozoic Fossils of Cornwall, Devon, and West Somerset, p. 190.

part of the Petherwin group cuts the sea-coast, near Boscastle, we observe a somewhat marked line of separation between the roofing and common argillaceous slates there forming the upper part of the Petherwin beds, and the carbonaceous slates and grits, and see, interstratified with the latter, a thin bed of schistose trappean ash.* It is difficult to assign the trappean ash of Lesnewth more to one group than to the other, and the same difficulty is continued to Hallworthy. Still, however, a somewhat marked boundary line can be traced by Lesnewth, Wilsey Down, Coose Moor, and Laneast Down, towards South Petherwin. From thence to Tavistock no firm line can be drawn, and the beds of the Petherwin group and the carbonaceous rocks above it are intermingled with various trappean rocks, among which trappean ash is abundant, pointing to considerable igneous action and accumulations in this part of the general area while the change was taking place from ordinary detrital deposits, sometimes mingled with calcareous matter, to those in which carbon was abundantly disseminated among the mud, sands and limestones afterwards accumulated.† Although there are many good localities where the intermixture of the igneous rocks with the continuation of the Petherwin group and the carbonaceous series, as also with the passage-beds between them, may be studied, the volcanic character of the igneous rocks themselves is seldom better exhibited than at Brent Tor. This tor, which is a remarkable object in the county (1100 feet above the sea), presents us with a mixture of trap rocks, ash, and a conglomerate containing vesicular portions of igneous rocks, which approach the condition of pumice when the contents of the vesicles, the results of infiltration being often siliceous, are weathered out. These rocks are associated in a manner such as is often seen in volcanic countries, and the tor may be regarded as a sectional portion of such igneous accumulations, mingled with some more common detritus of a date corresponding with the lower carbonaceous accumulations of North Devon.‡

Though deprived of a defined line of demarcation between the Petherwin group and the lower part of the carbonaceous series, we fortunately, in a range of country extending from Launceston to Oakhampton, have, as was pointed out by Professor Sedgwick and Mr. Murchison,§ the frequent occurrence of black carbonaceous limestone, which may be regarded as the southern outcrop of the black carbonaceous limestones

* Report, &c., plate iv. fig. 1.

† For a more detailed account of this part of the county, see Report, &c., p. 106, and plate iv. figs. 2, 3, and 4, and Sedgwick and Murchison on the Physical Structure of Devonshire, &c., Geol. Trans., Second Series, p. 671, plate li. fig. 7.

‡ For a section through Brent Tor, and the mode in which its rocks are associated with the lower part of the carbonaceous series, see Report, &c. plate iv. fig. 4.

§ Physical Structure of Devonshire, &c.

of North Devon, containing similar fossils with them. At the period of this black limestone the chief volcanic action exerted between Launceston and Dartmoor on the east would appear to have ceased, the great accumulations of solid trappean rocks and of ash having taken place anterior to its production.

From the passage of the Petherwin group into the lower part of the carbonaceous series, it becomes interesting to inquire as to the extent to which any organic remains discovered in the lower may have been continued into the higher series. Fortunately the vicinity of Launceston is useful in this respect, the Petherwin beds being richest in organic forms near South Petherwin, and the general succession of deposits being determinable. We there obtain the following

*Section of Rocks based on the Petherwin Limestones.**

1. Sandstones, arenaceous and argillaceous shales.
2. Greenstone of Higher Truscott.
3. Sandstone and argillaceous slate, in which manganese occurs.
4. Carbonaceous limestone and roofing-slate.
5. Argillaceous slate.
6. Trappean ash of Higher Trebursey, near Launceston.
7. Argillaceous slate, with some sandstone.
8. Carbonaceous slate, used for roofing, with Posidoniæ and vegetable impressions.
9. Argillaceous slate.
10. Limestones and slates, containing numerous fossils (p. 80), and among them vegetable impressions.

Professor Phillips refers the upper beds to the Coddon Hill grits of North Devon, and states that in the Truscott limestones Goniatites (*G. crinistria*, *G. mixolobus*) are not umcommon, and that he found Posidoniæ (*P. Becheri*), crinoidal stems and plants (*Neuropteris* and *Lepidostropus*) in them.† He also directs attention to some beds at Yealm Bridge, near Launceston, included within the carbonaceous area, and containing *Turbinolopsis pluriradialis*, Bellerophontes (*B. hiulcus*), &c.‡

The continuation of the carbonaceous limestone, though only developed in patches, can be readily traced to Lew Trenchard and Bridestow, round the northern side of the Dartmoor granite, by Oakhampton and South Tawton, to Drewsteignton. Further eastward there is much uncertainty. The limestones of Chudleigh, furnishing black marble, so occur amid the carbonaceous rocks in that direction as to suggest the inference that they may be included among it in the same manner as the Holcombe Rogus and Westleigh limestones on the north, and therefore slightly mixed with slates without carbonaceous matter.§ Mr. Austen considers the Chudleigh limestones as more nearly allied to the

* The section is shown, Report, &c. plate iv. fig. 2.

† Palæozoic Fossils of Cornwall, Devon, &c., p. 195.

‡ Ibid., p. 180.

§ Report, &c., plate iv. figs. 7 and 8.

older slate and limestone series of South Devon, and states that the abundance of *Favosites fibrosa* in it is similar to the Ashburton and Plymouth limestone, that it contains *Stromatopora concentrica*, in common with all the subordinate Broadhempston and Staverton limestone bands; the *Stromatopora polymorpha* and large *Strygocephali* of the Ogwell beds, and the *Loxomena prœterita* and *Buccinum spinosum* so numerous at Newton Bushell.*

The connexion of this fauna with that of the adjacent limestone and slate district would point to a recurrence of the general conditions under which the latter was produced, if we suppose the Chudleigh limestone higher in the series, and to a reversal of beds continued from the vicinity of Ashburton, in which direction the range of the Chudleigh beds would point. Connected with this view the occurrence of certain fossils, noticed by Professor Phillips at Combe, near Ashburton, in beds included in the carbonaceous series, is valuable. He there mentions *Turbinolopsis bina*, *T. celtica*, and small orthides, like *O. interlineata* and *O. flabellulum*, and points out the similarity of this fauna to that of the rocks at Mudstone Bay, though the mineral structure of the beds corresponds with part of the Coddon Hill grits, and the strata are associated with gritty rocks, like those of Chudleigh.† He remarks that the Combe beds appear to dip beneath the Ashburton limestones.

The position of these beds would agree well with a reversal of the rocks on the large scale, from Buckfastleigh ‡ to Chudleigh, and the continuance of some animals on the confines of the carbonaceous series and subjacent rocks, under suitable conditions, locally upwards. The fossils discovered in the beds at Yealm Bridge, near Launceston, would also seem to require the same explanation as regards their geological position, since they are apparently included in the carbonaceous series.

Professor Sedgwick and Mr. Murchison, who were the first, in 1836,§ to point out that the culmiferous deposits, as they termed them, of Devonshire were probably equivalent, in part at least, to the true coal measures, divided these deposits into *Upper* and *Lower Culm Measures*, considering the former referable to the coal measures, and leaving the geological position of the latter doubtful.‖ They mention the passage of the base of the lower division into the subjacent older rocks, and limit this division upwards to the black limestone range inclusive.

* On the Geology of the South-East of Devonshire, Geol. Trans., Second Series, vol. vi. p. 466. Mr. Austen gives sections of the Chudleigh limestone district, Ibid., plate xlii. figs. 6 and 8.

† Palæozoic Fossils of Cornwall, Devon, &c., p. 180.

‡ For a section of the Buckfastleigh country see Report, &c. pl. vi. fig. 6.

§ Meeting of the British Association at Bristol.

‖ On the Physical Structure of Devonshire, &c., Geological Transactions, Second Series, vol. v. p. 670, &c.

Goniatites and Posidoniæ are shown to be abundant in the lower division, especially among the limestones and associated shales, and a species of Posidonia is described as making a near approach to one found in the upper carboniferous limestone shales of Northumberland, not far below the Millstone Grit. On the whole, they would appear to consider this division as referable to some part of the carboniferous limestone series.*

Professor Phillips takes a similar view, observing that the few shells yet obtained from the carbonaceous group are mostly referable to the carboniferous limestone, pointing out the following:—*Pleurorhynchus minax*, *Posidonia tuberculata*, *Leptæna mesaloba*, *Orthis Hardrensis*, *Goniatites spiralis*, *G. crenistria*, *G. mixolobus*, *G. spirorbis*, and *G. serpentinus.*† He, at the same time, notices the equivocal character of the geological evidence at Combe, near Ashburton, and remarks on the fossils of the Yealm Bridge beds as associating the rocks containing them, with the Petherwin group. With respect to the *Posidonia Becheri*, so common in the black shales and limestones, both on the north and south ranges of these beds, the lists of Mr. Griffith show this species to be very abundant in the *Calp* of Ireland, a division of the carboniferous series of that country between the upper and lower carboniferous limestones.‡ The same lists show *Posidonia lateralis* and *P. tuberculata*, as also common in the Irish Calp. According to the same catalogues, the *Atrypa insperata* of Coddon Hill, the *Orthoceras cylindraceum* of Swimbridge, and the *Turbinolopsis bina*, *T. celtica*, *Sanguinolaria sulcata*, and *Orthis interlineata* of Combe, near Ashburton, are discovered in carboniferous limestone of Ireland.

As the prolongation of a sheet of matter, chiefly calcareous, occupying a considerable portion of the British Isles, especially in Ireland, the district which has been above noticed, becomes interesting from exhibiting a marked change or modification in the lower part of the series, it being assumed that there is sufficient evidence to show that the upper part, at least, of the Devonian rocks, the Pilton and Petherwin groups, for example, in a great measure represent the lower carboniferous limestones, shales, and sandstones of South Wales, Dean Forest, the Bristol district, and of the Mendip Hills.

* In the list of fossils which accompanies the Memoir of Professor Sedgwick and Mr. Murchison, *Posidonia lateralis*, *P. Becheri*, and *P. tuberculata*, are noticed as found near Barnstaple, and *Goniatites carbonarius* and *G. vinctus*, as from the same vicinity. *P. tuberculata* is considered by Mr. Sowerby to be the same with the species so named and found at Buddle, near Bamborough.

† Palæozoic Fossils of Cornwall, Devon, &c., p. 180.

‡ Notice respecting the fossils of the mountain limestone of Ireland, p. 13. Professor Sedgwick and Mr. Murchison, had also mentioned Posidoniæ as discovered in the Irish *Calp*. Geol. Trans., Second Series, vol. v. p. 693.

It is not to be expected that we should find exact equivalents for all parts of this considerable deposit, in a great measure formed of carbonate of lime, in every sequence of beds, which as a whole may be referable to the same date, if we have regard to any probable mode of accumulation at all in accordance with that of the present day. We should anticipate that beds of broken encrinites would be accumulated in one place more abundantly than in another; coral reefs the same. Deposits, occupying a less area than those immediately preceding or succeeding them, would not, necessarily, be discovered in sections out of that area, and numerous differences may be expected horizontally, and from minor deposits overlapping preceding accumulations more in one direction than in another. With due attention to such minor influences and effects, there are, however, certain large divisions, the local and general modifications of which are important, when we seek for the probable conditions under which the whole has been accumulated. By the aid of the sections in southern Ireland, first observed by Mr. C. W. Hamilton,* and the geological researches of Mr. Griffith and the organic remains enumerated by him,† we are enabled to consider the upper part, at least, of the Devonian deposits as having been accumulated under somewhat similar circumstances, in an area extending from Devon and Cornwall to Southern Ireland. Mud, sometimes impregnated with peroxide of iron, was abundant, and sands were mingled with it. Although carbonate of lime was often disseminated among the detritus, limestones were subordinate to the general mass.

Without attempting any exact equivalents, it will be sufficient, making all allowances for errors in the determination of the fossil species, viewed as common to Devon and Southern Ireland, that we

* In 1837, Mr. C. W. Hamilton, President of the Geological Society of Dublin, pointed out the general relations of the carboniferous slates and old red sandstone in Kerry.—Journal of the Geological Society of Dublin, vol. i. p. 276. In a note, published in the London and Edinburgh Philosophical Magazine, vol. xiv. p. 317 (1839), Professor Sedgwick and Mr. Murchison refer to this communication as supporting their views respecting the probable development of the Devonian System in Ireland, and as showing that the slates, previously termed grauwacke slate, occupied a great extent of country above the old red sandstone, and supporting the carboniferous limestone into which they pass, the old red conglomerate resting unconformably upon a great thickness of older slates and conglomerates. In 1839 (Phil. Mag., vol. xv. p. 443), Mr. Hamilton published a Paper on the succession of the older stratified rocks in the neighbourhood of Killarney and Dublin, and further noticed the rocks which he considered intermediate between the old red sandstone and carboniferous limestone, and to be constantly and clearly distinguished from both, pointing them out as Devonian.

† The views of Mr. Griffith on the South of Ireland will be seen in his memoir, 'On the Principle of Colouring adopted for the Geological Map of Ireland, and on the Geological structure of the South of Ireland' (read June, 1839), Journal of the Geological Society of Dublin, vol. ii. p. 78. The enumeration of organic remains is contained in his Notice respecting the Fossils of the Mountain Limestone of Ireland, Dublin, 1842.

consider the Pilton and Petherwin groups to have been formed at about the same geological time with the Southern Irish beds known as the carboniferous slates and yellow sandstone; that is, that the system of mud and sand banks, together with some calcareous matter, of the one district extended to the other, the creatures existing upon or in the banks being similar, with proper allowances for difference of distribution, in both localities. Proceeding northerly and north-east from Devon, we find mud and sands, mingled with calcareous matter, forming the base of the carboniferous limestone of South Wales, Monmouthshire, Dean Forest, the Bristol district, and the Mendips. We can readily consider these mud and sand banks and calcareous deposits as an extension of similar accumulations in Devon, so far formed under dissimilar circumstances, that in the localities above named we find them unequivocally separated from the Silurian rocks by a thick mass of the old red sandstone, and therefore under modified conditions from their supposed mode of occurrence in Devon, conditions which might materially influence the local destruction of animals living at the Silurian period.

These mud, sand, and calcareous beds, are found to fine off northward, the higher beds of limestones overlapping them, so that we obtain a boundary for them in that direction, and might suppose an original shelving sea-bottom, the sea above it increasing in depth southwards, thus permitting much thicker accumulations in that direction than northward, at the same geological period.

Above these sands, mud, and limestone, the remains of myriads of encrinites formed thick beds, which stretched from the Mendip Hills to Southern Pembrokeshire, becoming thinner to the northward, and not extending into Devonshire and Cornwall, except, if they do so, in a minor and modified form. A great thickness of limestones, many beds of which have the appearance of coral reefs, especially in the upper part, cover the great encrinite banks, though encrinites are not absent from them, being on the contrary, often numerous. How far any of the upper beds beneath the Devonian black limestones may be of this age, it is very difficult to say; but should any of them be so, the mass of limestones which constitute so marked a feature of the country extending from the Mendip Hills to Pembrokeshire, is absent, and we have to consider either that detrital beds have in a great measure replaced it in Devonshire, or that local conditions prevented any equivalent accumulations there at that time.

If we take the range of the carboniferous limestone from Haverfordwest on the north side of the coal measures to Pontypool, the upper beds are somewhat suddenly separated from the coal measures above them. At Dean Forest (section, p. 127), we find that sand banks,

alternated with the calcareous deposits. Conditions for the same results extended round by the Tortworth district to Bristol (p. 113), where there was a marked interstratification of mud, sands, and limestone, the latter sometimes containing water-worn pebbles. In the Mendip Hills these alternations appear more modified.

Sweeping round from Pontypool, by Llantrissant, towards Swansea, there are no marked alternations of sandstones or marls with the upper beds of limestones, so that the area thus characterised would appear one chiefly extending from Dean Forest by the Tortworth and Bristol districts, to the Mendip Hills. At Swansea we observe a development of the black shales and cherty grits above noticed (p. 133), fining off at Tenby, where we see black limestones with Goniatites, the whole of these beds so intervening between the more solid carboniferous limestone and coal measures appearing as if they were a continuation of the black limestone group of Devonshire, above the Pilton and Petherwin groups, thus extending, locally modified, into South Wales. Under this view, the close of the carboniferous limestone epoch would, in South Western England and South Wales, be marked by an unmixed deposit of limestone in one part, an alternation of sands, mud, and limestone in another, and by sands, black mud, and carbonaceous limestones in a third.*

Coal Measures.

The accumulations over the districts above noticed became now completely altered in character, more especially as regards extensive beds of carbonaceous matter included among the sands and mud of the time, and the absence of organic remains to which a marine origin might be assigned. Though a kind of coal seam was noticed in the Avon section among the upper beds of the carboniferous limestone series, a long period seems to have elapsed before the conditions were such as to present the accumulation of numerous coal beds in that vicinity. Over a large part of the area under consideration, thick and extensive beds of sands, in some localities mingled with gravel, were drifted over the carboniferous limestone series beneath. For a long distance, extending from Haverfordwest to Pontypool, and thence round towards the neighbourhood of Bridgend, though variable in depth, the sands and gravels were chiefly composed of white quartz, the beds of which are for the most part now consolidated into a very hard rock, often approaching to quartz rock. Not only was the mass of the original sands and gravels white,

* It is worthy of observation, that in the continuation of the carboniferous limestone area into Ireland, the Kilkenny coal district, the nearest patch of coal measures to those of Pembrokeshire, shows the upper part of the carboniferous limestone to be formed of limestones, in which there is much black chert, surmounted by flinty slates, above which are black carbonaceous shales, with Goniatites and some other fossils.

the accumulation of a considerable depth of detrital quartz, but the cementing matter over a wide space also appears to have been little else than nearly white and siliceous. A state of things not uncommon in many deposits of different ages, where nearly pure quartz grains became cemented together. Here and there mud beds are intermingled with these sands, for the most part black and carbonaceous, and sometimes these and ordinary silt and gray mud beds have been much interstratified with the white sandstones and conglomerates.

In Dean Forest the beds are more coloured, and near Bristol, and also on the skirts of the Mendip Hills, they are frequently red, from an admixture of peroxide of iron. They still, however, present a somewhat general character as to composition, so that we have to consider a large accumulation of sand and gravel, occasionally mingled with mud and silt, as spread over a wide space, extending from the Mendip Hills to Southern Pembrokeshire, with modifying conditions in Gower and near Tenby, which render it difficult to draw fine lines of distinction between the carboniferous limestone and coal measures in those localities. Indeed, the like difficulty occurs in Dean Forest, the neighbourhood of Bristol, and the Mendip Hills, where we find sandstones alternating with the upper limestone beds, the latter in this manner gradually disappearing, while the conditions for sand-drift finally prevailed.

To these beds the name of millstone grit has been assigned by Dr. Buckland and Mr. Conybeare, who considered them of the same geological age as the millstone grit of Northern and Central England.* The miners of South Wales and Monmouthshire commonly know the deposit as the Farewell Rock, since, in the descending order, workable coal ceases to be found in it.

By the sections these beds would appear very thick in the vicinity of Bristol, where they seem at least 950 feet deep, and on the northern skirts of the Mendip Hills they are also thick. The Dean Forest sections give about 270 feet for this deposit, a depth which, at Pontypool, is decreased to about 200 feet. It thence appears to increase in thickness toward Merthyr Tydfil, where the measurements give 330 feet. From its great hardness it forms a marked feature among the rocks ranging along the mountain outcrop of the lower coal measures extending from the vicinity of Pontypool into Caermarthenshire, and it also constitutes marked ground for a similar reason on the north crop of the coal measures in Pembrokeshire. Large scattered blocks of white or light-coloured sandstones and conglomerates commonly mark its presence in this range, and the soils above it are for the most part very poor and sterile.

* Observations on the South-western Coal Districts of England, Geol. Trans., Second Series, vol. i. p. 252.

Judging from sections, the chief thickness of this sand and gravel deposit is to be found in Gloucestershire and Somerset, the accumulations becoming thinner to the westward. One or two thin coal seams are now and then discovered in it from the Mendips to Pembrokeshire. One occurs low down, not far above its base, near Cribarth, Brecknockshire, such seams being accompanied by underclay, a kind of bed found beneath all the true coal beds of South Wales, Monmouthshire, Gloucestershire, and Somerset, and possessing high interest when viewed in connexion with the origin of the coal itself.

As the occurrence of these peculiar beds beneath the coal will require to be often mentioned, it may be desirable here to notice them. When, in 1837, the Geological Survey commenced its labours in the coal district near Swansea, Mr. Logan, who had for several years previously been engaged in a careful examination of that district (which he completed, and, with true public spirit, presented to the Geological Survey, of whose maps, after due examination, it now forms a conspicuous part), pointed out to us the constant occurrence of a marked kind of bed, with a peculiar fossil plant, as observable beneath all the coal beds he had examined. The fossil plant was the *Stigmaria ficoides*. Subsequently, in 1840, Mr. Logan published an account of these beds,* showing that they vary in thickness from a few inches to more than 10 feet, and are penetrated in all directions by a confused and tangled collection of the roots and leaves, as they may be, of the *Stigmaria ficoides*, these being frequently traceable to the main stem, which varies in diameter from about two inches to half a foot. The main stems are noticed as occurring nearer the top than the bottom of the bed, as usually of considerable length, the leaves or roots radiating from them in a tortuous irregular course to considerable distances, and as so mingled with the underclay that it is not possible to cut out a cubic foot of it which does not contain portions of the plant.†

As Mr. Logan observes, these beds are commonly more or less argillaceous, with a mixture of sand, "yielding, in most instances, a very good fireclay,"‡ for which, indeed, many of them are employed. Though usually tough and hard to work in the coal mines, they easily crumble when exposed to the weather, so as readily to be distinguished from the ordinary shales thrown out of the pits. When well worked up with

* On the Characters of the Beds of Clay immediately below the Coal Seams of South Wales, and on the occurrence of Boulders of Coal in the Pennant Grit of that District, Geol. Transactions, Second Series, vol. vi. p. 491. Mr. Logan had previously published an account of these beds in the Annual Report of the Royal Institution of South Wales, for 1839.

† Ib. p. 492.

‡ On the Characters of the Beds of Clay immediately below the Coal Seams of South Wales, &c., Geol. Trans., Second Series, vol. vi. p. 492.

water they commonly form a kind of silty mud, varying in the quantity of its arenaceous matter, the original condition, probably, of the greater part of these underclays.

Though long known to coal-miners under various names, such as *Gwely* (Welsh for bed), in Cwm Rhondda and Cwm Taff; *Careg lower*, a strange mixture of Welsh and English, literally *Stone lower*, in the west of Glamorganshire and Caermarthenshire; *Underclay*, *Bottom Stone*, and *Undercliff*, in Cwm Tawe, and in the vicinity of Swansea; *Pouncin*, at Neath, Cwm Afon, Cwm Garw, and Cwm Ogwr, and by other terms, it is remarkable how few coalpit sections take any notice of these beds, even to the present time, unless it be any underclay furnishing, or capable of furnishing, good fireclay. We have not unfrequently had its existence denied, when, upon entering a coal level or descending a pit, its presence was evident. This chiefly happens when the bed is hard, containing a large quantity of sand, so as to approach the character of sandstone. Mr. Logan notices such a variety beneath the *Farm Seam* of coal, not far from Penclawdd, on the Bury River, as presenting the appearance of a sandstone sufficiently durable to be employed for building purposes. It was, however, "penetrated, like all the rest, by the long fibrous processes of the Stigmaria, though not quite in the usual abundance." Sometimes, without being altogether arenaceous, the bed is highly siliceous, and as hard as some quartz rocks. Two underbeds of this description occur on the seashore near Lilliput, between Swansea and the Mumbles. Being doubtful if they were really equivalent to the common underclays, though they contained *Stigmaria ficoides* disseminated in the usual manner, the beach through which they protruded, on account of their hardness, was removed, and seams of coal found above both.* In this case we would appear to require the infiltration of a considerable amount of silica upon consolidation of the beds. Other instances of the like kind have been observed, and much modification may be seen, as might be expected, upon tracing the course of known and well-worked beds of coal for long distances.†

* For the positions of these beds, see Vertical Sections of the Geological Survey of Great Britain, sheet 6.

† Mr. David Williams, of the Geological Survey, has reported on this head that beneath the Four Feet Coal at Merthyr Tydfil the bed is very hard, while, in the continuation of the beds at Romney, a fireclay occupies the same position; that at Beaufort and Ebbw Vale there is hard rock beneath the *Old Coal*, while a thick bed of fireclay is found under it at Nant-y-glo. At Blaina, a little to the south, the hard rock again comes in, with, however, 14 inches of fireclay next to the coal. In Cwm Celyn deep pit the bed of fireclay disappears, and a hard rock supports the *Old Coal*. At Farteg a fireclay is interposed between the hard rock and the coal, which, however, disappears at Pontypool, the *Stone Vein* there, the continuation, as considered by Mr. Williams, of the *Four Feet Coal* of Merthyr Tydfil, and of the *Old Coal* of Nant y glo, being based on hard rock.

These underbeds are now known to be common in coal districts referable to the palæozoic series. We have observed them beneath all the true coal beds we have seen, in Great Britain and Ireland. Mr. Logan notices them in Ayrshire, where they are known by the name of *fakes*, and he detected them in the United States (in 1841) under the coal seams of the anthracite regions of Pottsville, Wyoming, and of Wilkesbarre, on the Susquehanna. Dr. Rogers then informed him that they were discovered in the same position, relatively to the coal beds, in the continuation of the coal district into Virginia. Mr. Logan afterwards observed them in a similar position in the coal country of Nova Scotia.*

Mr. Lyell, who has devoted much attention to, and carefully examined the underclays of the American coal fields, points out their common occurrence in that part of the world beneath the coal beds,† so that some very general conditions must have produced these beds over so large a portion of the earth's surface, conditions with which the production of the coal itself would appear to be connected.

In Aikin's Dictionary of Chemistry and Mineralogy (1807) it is stated, under the head of *Coal*, that "beneath each stratum of coal is generally a stratum of somewhat greasy indurated clay, called by the miners, *clunch*, which is usually, if not always, destitute of those organic remains that characterise the shale." In this case, though the peculiar kind of bed was observed, and, from the name employed, probably in the midland or northern counties of England, no mention is made of the prevalence of a particular fossil plant in it. In 1818, Mr. Weaver observed that the whole substance of the fireclay beneath the Kilkenny coal was interwoven with vegetable impressions. He also gave a good general account of that fireclay.‡ As Mr. Logan has remarked, though Mr. Steinhauer early described (1818) the mode of occurrence of *Stigmaria ficoides*,§ he does not appear to have been struck with the general relation of the beds containing this fossil plant to the coal beds. Speaking of the central stem and its radiating branches or roots, traceable to the distance of 20 feet from the former, Mr. Steinhauer observes:—

"Repeated observations and the conviction of unprejudiced persons made attentive to the phenomena, compelled the belief that they (the

* Geological Transactions, Second Series, vol. vi. p. 495, note.

† Travels in North America, with Geological Observations, vol. i. p. 84, vol. ii. p. 18, and 185, and Proceedings of the Geological Society of London, vol. iii. p. 554. 1845.

‡ On the Geological Relations of the East of Ireland, Geological Transactions, First Series, vol. v. p. 290. Mr. Weaver says, "the fireclay beneath the coal (of Kilkenny) varies from four to nine feet in thickness. It is of a blackish or bluish-gray colour, more or less indurated and tenacious, but on exposure to the atmosphere it soon disintegrates into powder. Burnt in a strong fire, it becomes white and very hard. The whole substance of the fireclay is, in a manner, interwoven with vegetable impressions, apparently belonging to the grasses, which, when fresh, have a rich, glossy, and almost silky aspect."

§ American Philosophical Transactions, vol. i.

radiating portions) originally belonged to the trunks in question, and consequently that the vegetable grew in its present horizontal position at a time when the stratum was in a state capable of supporting its vegetation, and shot out its fibres in every direction through the yielding mud; for if it grew erect, even admitting the fibres to have been as rigid as the firmest species with which we are acquainted, it would be difficult to devise means gentle enough to bring it into a recumbent posture without deranging their position. This supposition gains strength from the circumstance that they are found lying in all directions across one another, and not directed against any particular point of the compass."*

The necessity of a soft or readily yielding state of the medium in which the Stigmaria grew, and of its actual growth in the beds where we find it entombed, long slender leaves or shoots radiating to considerable distances from its stem, appears, with Mr. Steinhauer, to have forcibly struck all who have carefully observed these Stigmaria beds.

Since the lithological character of these deposits seems to depend chiefly upon the manner of their consolidation, their original differences having been principally produced by variable quantities of sand in their composition, we appear to have evidence of some very constant physical conditions both for the mineral matter of which the beds are composed, and for the growth of the particular plants found in them, and this not over a limited area, such as the coal fields of South Wales and South-western England, but for a widely-spread system of coal accumulations in distant parts of our northern hemisphere. Whatever these conditions may have been, they were similar and often repeated, even in the same area, though irregularly interrupted by others not favourable to the formation of the underbeds, both in Europe and North America, but for what range of geological time, and how much more widely spread, it remains for the progress of geology to ascertain.

While carefully investigating the mode of occurrence of the underbeds,† for the study of which the sections in South Wales, especially, afford such excellent opportunities, it soon appears that, however constant as regards their position beneath, or association with coal, there is no constancy as respects the kind of beds on which they rest. These may either have been gravel, sand, or mud, of any thickness, and in any way combined. Here and there, though not frequent in the district, a bed of this character may be observed without a covering of coal, as if the conditions requiring this coal covering had not

* American Philosophical Transactions, New Series, vol. i. p. 268.

† This will be well seen by reference to the various coal measure sections of South Wales, Monmouthshire, Gloucestershire, and Somerset, Vertical Sections of the Geological Survey of Great Britain, sheets 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, and 11.

been attained, the accumulation having been interrupted before it reached the time for the coal. Often, however, when it has been stated that there was no coal to be seen above good lithological underbeds, with Stigmaria, even when used for fire-clay, from one to three inches of coal were observable, upon careful search, in a good section, the coal condition having only obtained for a comparatively short period.* At the same time it is easy to imagine that any given underclay may have been locally interrupted at half or any other portion of its thickness. Indeed, as the beds of coal increase or diminish in thickness, the underclay has necessarily a varying height of coal above it, amounting sometimes to a mere trace, and even to a total disappearance from local causes. The main point is, that throughout South Wales, Monmouthshire, Gloucestershire, and Somerset, wherever we could obtain a good section, we have not seen a true coal bed without a subjacent stratum of the kind here noticed, and though frequently informed that it was not the case, in certain localities, careful search has hitherto always shown us that such was nevertheless the fact. We have often seen irregular accumulations, even several inches thick, formed of drifted plants, chiefly *Sigillaria*, principally among the sandstones, such accumulations occasionally somewhat extensive, but there is little difficulty in separating them from the true coal beds, often spread over square miles of country, even when only of very limited depth.

The real character of the remarkable plant, *Stigmaria ficoides*, discovered so abundantly and constantly in the peculiar beds immediately subjacent to the coal, seems still a matter of doubt, notwithstanding all that has been written concerning it.† Professor Goeppert, in his 'Gat-

* That beds in every respect resembling those beneath coal beds, and in like manner containing *Stigmaria ficoides* abundantly disseminated through them, occur without coal, is well known; they still, however, mark peculiar conditions, and point to the growth of the Stigmaria in them, when the leaves or radicles radiate from the stems.

† Llwyd would appear to have been the first who noticed this plant in the South Welsh and Monmouthshire coal district. In his letter to Dr. Tancred Robinson, dated Usk, 15th June, 1697 (published in the Philosophical Transactions for April, May, and June, 1712, vol. xxvii. p. 467), he describes a fossil which appears to have been a Stigmaria. The account of the coal level is also interesting, as showing the mode of working adopted at that time. "Advancing," he says, "about three miles further into Brecknockshire, at a place called Llan Elhi (Llanelly), we reached some coal and iron mines. Their coal works were not pits sunk like draw-wells; but great inroads made into the side of the hill, so that three or four horsemen might ride in abreast. The top is supported with pillars left at certain distances; and they make their by-lanes (as in other pits) as the vein requires. The slate above this coal afforded many stalks of plants, which we did not save, because it seemed impossible to reduce them to their several species. However, close to the pit we found a valuable curiosity, viz., a stone for substance like those they make lime of; of a compressed cylinder form; and as it were cut off even at each end; about eight inches long, and three in breadth. Its superficies adorned with equidistant dimples, like Dr. Plot's *Lepidotes*, Hist. Oxfordshire, chap. v. par. 55 (the figure of Plot bears a rude resemblance to Stigmaria), and in each dimple a small circle; and in the centre of each

tungen der fossilen Pflanzen,' 1841, has, in great detail, treated of this fossil plant, and noticed all the opinions respecting it, from Petiver (1704) and Volkmann (1720) to the time in which he wrote. After a careful and detailed examination of the evidence respecting the structure of *Stigmaria ficoides*, Professor Goeppert concludes, that it did not belong to the dicotyledonous, but to the monocotyledonous plants, and even to those of an inferior order; and that, organized as it is, it could only be a terrestrial, and not an aquatic plant.*

M. Adolphe Brongniart, after describing this plant, in which, with *Sigillaria elegans* and *Anabathra pulcherrima*, he finds the vascular system of the Coniferæ and Cycadeæ, joined to the essential characters of the vessels of the Ferns and Lycopodiaceæ (considering the Stigmaria as intermediate between the Cycadeæ and Sigillariæ†), observes, that perhaps the Stigmaria may be but the roots of the Sigillariæ, the recumbent position of the stems and the rounded form of the cicatrices according with this supposition; against which may be urged, he remarks, the regular disposition of the appendices, which would then have to be compared with radicles, a regularity, however, rather frequently found in the roots of aquatic plants.‡ Mr. Binney considers that he has found confirmation of these views at St. Helens, in Lancashire, where he regards the relative position of Stigmariæ to the stem of a Sigillaria to be such as to establish this conclusion.§

Be the real relation of this remarkable plant to others what it may, it, at all events, occurs in the beds immediately subjacent to the coal in South Wales and South-Western England, and in many other coal districts, in a manner justifying the conclusion, that it grew in such beds—then in a condition to permit the ready penetration of the

circle a small stud like a pin's head." Noticing the coal and iron mines then worked at Pontypool (p. 468), Llwyd mentions leaves of "capillary plants" in the iron ore.

* Die Gattungen der fossilen Pflanzen vergleichen mit denen der Jetztwelt. Bonn, 1841. Professor Goeppert, provisionally, until the fructification be known, places it among the cryptogamic monocotyledons. It agrees with the Lycopodiaceæ and Lepidodendraceæ by the dichotomous character of its branches, its cellular leaves, and other points. With the Cycadeæ it also agrees in some points. It differs, however, from both, and Professor Goeppert regards it as the type of a family between the Lycopodiaceæ and Cycadeæ, filling up a vacant space in our existing flora, thus affording, as he remarks, an additional instance of the existing and fossil plants forming but one flora, the families of which constituted an harmonious whole by means of multiplied intermediate forms, found sometimes now living, at others entombed in rocks.

† Archives du Muséum d'Histoire Naturelle, tom. i. p. 425 and 441.

‡ Ibid., p. 448.—M. Adolphe Brongniart further adds, that the central structure of Stigmaria, would not be a very grave objection, since he had observed a similar structure in the roots of many Zamia; it being especially apparent in the roots of *Zamia pungens*.

§ Letter read before the Geological Society of London, June 4, 1845. A valuable account of Sigillariæ and Stigmariæ is given by Mr. King in the Edinburgh New Phil. Journal, vols. xxxvi. xxxvii. and xxxviii. He supports the view that Stigmariæ are the roots of Sigillariæ.

slender leaves, or radicles, as they may be—to the distance of many feet from their parent stems. We thus obtain the probability of a soft condition for such beds amounting to mud, more or less mingled with sand, a view taken by Professor Lindley and Mr. Hutton in 1835, who, after noticing the manner in which the plant commonly occurs in its bed, the leaves shooting for many feet into the surrounding shales, remark that, "from all these circumstances, we are compelled to conclude that these Stigmaria were not floated from a distance, but that, on the contrary, they grew in the spots where we now find their remains—in the soft mud, most likely, of still and shallow water." *

Although occasionally the stem of a Sigillaria, of a Calamite, or of a Lepidodendron, with now and then the leaf of a fern, may be mingled with the Stigmaria in the lower part of an under bed to the coal, these plants are rarely obtained towards the top, where the Stigmariæ are usually in abundance. As yet, we have not been able, in this district, to trace Sigillaria stems from the underbed into the coal, though here and there, in the body of the coal, such stems, with those of Lepidodendron, are discovered reposing in the plane of the bed. Sometimes the line of contact between a bed of coal and its underbed is strongly marked; at others, a kind of carbonaceous shale is found, as if the vegetable matter rested at times directly upon the underbed, while it was intermingled with mud in the lower part at others.†

The occurrence of a bed full of *Stigmaria ficoides* beneath coal, though, to a certain extent, variable in lithological character, and the fair inference that this plant did really grow in the bed, and in great abundance, has led to the greater extension of an opinion, first promulgated by De Luc in 1793-5, that the coal itself is but the remains of plants which grew in the localities where we now find it.‡ De Luc considered the coal to have been formed from a kind of peat composed of a vegetation now unknown, the successive beds of coal having been produced by the sinking of the ground in which this peat grew, the

* Fossil Flora, vol. ii. *Preface*, p. xvii.

† It is by no means intended to assert that the Stigmaria stems may not be discovered in other beds than those in which they appear to have grown. As Mr. Logan has very correctly remarked, they may readily have been washed out of their original beds and deposited in some other then forming. After long and careful search we have been unable to find the stems so circumstanced in South Wales and South-Western England, though they may, no doubt, be found; indeed they are stated to have been so. At all events they would appear scarce out of the underclays, and we could not expect to discover them, with their radiating long delicate leaves or radicles, as they occur in the beds named underclays, whether these may or may not be covered by coal.

‡ Lettres sur l'Histoire Physique de la Terre, Paris, 1798. A revised edition of his Letters to Blumenbäch on the Physical History of the Earth, inserted in the British Critic for 1793, 1794 and 1795. These letters were republished in England, and with Notes by the Rev. H. de la Fite, in 1831. (London.)

peat beds themselves becoming covered by the other strata, which, when accumulated high enough for ground to appear, permitted fresh peat to grow upon it, and so on, the accumulations continuing to subside.*

Though often advocated, it has not been until lately that the growth of the plants composing the coal, in the localities where we now find it, has been received with much favour. The fact of so many trees, chiefly, it would appear, Sigillariæ, growing upright, the character of the underbeds supporting the coal, and the difficulty of supposing drifted plants to have accumulated in a manner to correspond with the mode of occurrence of the coal itself, viewed as a whole, have, however, led to the more general adoption of views somewhat similar to those of De Luc. M. Adolphe Brongniart has long supported this view.† In Lindley and Hutton's Fossil Flora of Great Britain, evidence is adduced to prove that a large amount of plants in the Durham and Northumberland coal measures grew where they are now found; and they consider that the coal was chiefly formed from vegetable matter which had lived, died, and was decomposed on the spots where we now observe it.‡ The same authors also point out the analogy with peat, and view coal beds as resulting from extended surfaces of marshy land, covered with rank luxuriant vegetation. Dr. Buckland, in 1841, gave a summary of the knowledge then existing on this subject, expressing his opinion that the *Stigmaria ficoides*, growing in ponds or lagoons in the localities where we now discover its remains, by mixture with mud or silts disseminated among them, formed the underbeds, upon which also grew the plants which now form the coal beds, these latter, by subsidence, being covered by sand or mud, forming sandstone or shale, between the coal strata, successive coal beds being formed as the necessary conditions arose.§

* This would appear to have been De Luc's general view, obscured as it may have been by the hypothesis of absorbing fluids, and by other opinions characterized by the state of geological knowledge of the day.

† M. Adolphe Brongniart, in his 'Considérations sur la Nature des Végétaux qui ont couvert la Surface de la Terre (1838),' p. 6, states that his late studies of coal deposits and peat districts have only confirmed him in his first opinions.

‡ Vol. ii. *Preface*, p. xxii.

§ Address delivered at the Anniversary Meeting of the Geological Society of London, 19th February, 1841. Dr. Buckland observes, "We may further admit, that by the deposition of mud or silt between the stems and leaves of Stigmaria, the bottom of each lagoon might have been overspread with the earthy sediments that compose the beds of fireclay immediately below the coal; and that the same lagoon, after the deposition of these sediments, continued crowded with Stigmariæ, accumulating on one another until they had entirely filled the lagoon with a matted mass of stems and leaves, as modern shallow lakes are gradually filled up and converted into peat bogs. The surface of the lagoon thus changed into a morass may forthwith have become covered with a luxuriant growth of marsh plants, *e. g.*, with Calamites, Lepidodendra, Sigillariæ, &c., the exuviæ of which

A coal bed is often marked by layers of different aspect, usually a few lines in thickness, like a compressed mass of matter differing somewhat in the mode of aggregation of its parts. The fibres are usually found to be parallel to the planes of the beds; the plants, such as Sigillaria, Lepedodendron, and Stigmaria (for these also have been discovered in it), occupy the same relative position; and everything seems to point to the effects of great pressure upon vegetable matter in layers of moderate depth, in which stems of Sigillaria, Lepidodendron, and Stigmaria were occasionally preserved in a recumbent state. To what extent the accumulation of similar plants with others may have formed the coal, the decay of one growth supporting another, or whether there may have been some peculiar plants furnishing the mass of the coal, the others accidentally introduced among them, is still matter for inquiry. Be this as it may, the conditions for the accumulation of the vegetable mass forming the coal were often subject to much interruption, for a coal bed is not often (taking the thickness of a considerable depth of coal measures) that simple body it may be supposed by those who have not attentively studied such beds, as well those which are not worth working as those which furnish fuel for consumption.

Even in beds where there is but a slight parting of carbonaceous shale, it sometimes happens that the lower coal may be of a different quality from the upper, commanding a different price in the market. The coal worked may also constitute but one bed among several of less depth, separated by different layers of shale, underclay, or even of sandstone. The following section of a coal bed (as the component parts would be collectively termed) above Fforch wen, Cwm garw, Glamorganshire, will illustrate the many interruptions the conditions for the production of the coal itself have sustained:—

	Ft.	In.
1. Arenaceous shale	4	0
2. Argillaceous shale	2	0
3. COAL	3	4
4. *Underclay* (Stigmaria)	0	6
5. COAL	0	3
6. Carbonaceous shale	0	2
7. COAL	0	3
8. Carbonaceous shale	0	3
9. COAL	0	6

formed a superstratum of vegetable matter convertible to coal, resting upon a substratum composed exclusively of remains of Stigmariæ. The regions which were the site of this vegetable growth may, by successive subsidences, have been so reduced below the level of the water, as to make them the receptacles of alternating deposits of sands and clay (now converted to strata of sandstone and shale) between the several beds of incipient coal. During these processes, successive series of lagoons may have covered large portions of each last-formed drift; and every lagoon becoming the site of a renewed growth of Stigmariæ, may thus continuously have been laying the foundation of future beds of inestimably precious fuel."

		Ft. In.
10.	*Underclay* (Stigmaria)	2 10
11.	COAL	0 4
12.	*Underclay* (Stigmaria)	0 4
13.	COAL	1 0
14.	Carbonaceous shale	0 10
15.	COAL	0 8
16.	Carbonaceous shale	0 8
17.	COAL	0 4
18.	*Underclay* (Stigmaria)	4 0

The subjoined section of a bed of coal, above Blaen Ogwr, in Cwm Ogwr, on the east of Llangeinor Mountain, on the west side of which the first section was obtained, will also illustrate the modifications of a coal accumulation :*—

		Ft. In.
1.	Argillo-arenaceous shale	7 0
2.	COAL	0 4
3.	Carbonaceous shale and COAL	0 5
4.	COAL	1 1
5.	Carbonaceous shale and COAL	0 6
6.	COAL	0 6
7.	*Underclay* (Stigmaria)	1 8
8.	COAL	2 10
9.	*Underclay*	2 0
10.	Carbonaceous shale and COAL	0 6
11.	*Underclay* (Stigmaria)	1 3

As showing similar kinds of interruption in the same locality at an earlier date in Cwm Garw, the following section of a coal bed, or rather seam, third beneath the first mentioned in that valley, may be useful :—

		Ft. In.
1.	Sandstone	
2.	Argillaceous shale	4 0
3.	COAL	0 7
4.	Carbonaceous shale	0 4
5.	Sandstone	0 2
6.	COAL	0 6
7.	*Underclay* (Stigmaria)	1 8
8.	COAL	0 10
9.	*Underclay* (Stigmaria)	2 0
10.	COAL	0 6
11.	*Underclay* (Stigmaria), thickness not seen	

In such cases as these, and they could readily be multiplied, we observe that there have been repeated conditions for the Stigmaria beds, while mud became so mixed with the vegetable matter occasionally as to produce local seams of carbonaceous shale. A slight sand drift amid vegetation is readily understood by those who have witnessed such drifts into peat bogs, or among any other accumulation of vegetable matter. Such sections also explain the statement fre-

* In seeking for evidence of this kind much care is often required, for amid varied alternations of coal, carbonaceous shale, and underclay, it sometimes happens that all is disregarded by the miner except the portion worked for profit, especially in the small collieries and coal levels.

quently made, that Stigmaria beds, in every respect resembling the usual underbeds, and furnishing good fireclay, often form the roof of a coal bed, and therefore that they occur as well above coal as beneath it.*

Coal beds, when fairly traced out, are seen to occupy very variable areas, as might be anticipated. While some mark the extension of coal conditions over a wide space, others are far more local, even those which are in places thick. Again, single coal beds become split up into two and even more beds, with interposed sandstones and shales. If we consider the carbonaceous shales of the first section (p. 153) as merely a mixture of mud introduced among the coal-forming plants, we have four underclays with Stigmaria, supporting as many growths of the needful plants, showing the elements of four separate coal beds, their relative thickness depending on the amount of accumulated vegetable matter in each. Should a drift of either mud or sand interpose between the top of one accumulation of plants and the base of the underclay above it, the system of coal beds noticed would be separated by the resulting shale or sandstone, and, after a range of some miles, this separation might, from local causes, amount to many feet. Upon carefully studying the split coal beds this is seen commonly to happen. As to a local interposition of common shales and sandstones between the parts of a coal bed, as before observed, the local drift of common mud or sand will account for such appearances, the coal plants having passed over the edges of such drifts, and established themselves on the top of them.

Though the general character of the beds supporting the coal seams of the district is constantly the same, the roofs of the coal beds vary considerably. In some we observe a carbonaceous shale pointing to an admixture of vegetable matter with the mud, which finally prevailing prevented the further growth of the plants. In others there is little or no mixture of the mud, and a more defined line marks the separation of the coal from the superjacent argillaceous shale. It is not uncommon in such cases to find a multitude of plants, often leaves of ferns, as if they had been drifted in the mud-charged waters over the growth of the plants, afterwards forming the coal. The delicate and uninjured structure of some of these drifted plants, scattered about in all directions, as we may see plants in many a tropical lagoon, would appear to show that the current in which they were moved had not been violently agitated.

When a sandstone roof covers the coal the separation of the coal from it is commonly well defined, though an occasional intermingling

* Mr. Logan points out this fact, observing that sometimes the roof of one coal seam is the floor of another. Geol. Transactions, Second Series, vol. vi. p. 493.

of the grains of sand with the carbonaceous matter may be observed, caused sometimes, apparently, by the removal and lifting of the top of the coaly mass, and by a mixture of the sand with it. From the surface state of the coal beneath many a sandstone roof we seem to have evidence that the friction of the sand and water has removed portions even at that time in a state capable of being acted on by such friction. One of the best instances appears to be that pointed out by Mr. Buddle in Dean Forest, and known as "*the Horse.*" * The Horse with its branches resembles a channel cut among a mass of vegetable matter, in a condition somewhat similar to that found in a peat bog. It ranges in a direction S. 31° E., in the bed of coal named the Coleford High Delf, for a length of about two miles, and a breadth of from 170 to 340 yards. A number of minor channels communicating with each other and the main channel are named *Lows*. Mr. Buddle compares *the Horse* to the bed of a river which has completely washed out the matter of the coal; and *the Lows* to those of smaller streams or rills of water, cutting only a smaller depth into it. The roof is formed of the ordinary sandstones elsewhere covering the continuation of the Coleford High Delf, filling up the various inequalities of *the Horse* and *the Lows*, with the occasional interposition of a thin layer of a black slaty substance. The coal in the furrows or *Lows* is generally intermixed with particles of the sand, as might be expected from the friction of water mixed with sand upon the matter of the coal.

The thinning off of many a coal bed in South Wales and Monmouthshire, with a sandstone roof, points to a removal by water and sand of a pre-existing base of vegetable matter, much in the same state. It should not, however, be inferred, that where there is a sandstone roof there has necessarily been a removal of vegetable matter beneath. Such would not happen when a depression permitted the accumulation of sand or gravel in a manner causing that arrangement of parts known as false bedding.† When we see such false bedding the apparent removal of the vegetable matter is more rare, except when we have to suppose that a sufficiently strong current of water cut into the vegetable mass beneath, before the sands could advance over it. In these sandstone roofs we rarely find, as might be expected, the delicate plants observed in the shales, but a more confused mass of hard plants, when there are any contained in them, such as the stems of Sigillaria, Lepidodendron, and Calamites.

* On the great Fault called the Horse in the Forest of Dean, Geological Transactions, Second Series, vol. vi. p. 215. Though termed a fault by the miners, since it cuts off the coal from them for a certain distance, *the Horse*, as Mr. Buddle observes, bears no resemblance to the dislocations called faults. The plan and section given of the *Horse* and *Lows* are extremely instructive.

† For observations on this kind of accumulation, see pp. 9 and 64.

Thus, though the Stigmaria in the underbeds, and the accumulated matter forming the coal appear referable to growth on the spot, the covering of the coal points to drift of different kinds, the finer sediment being thrown down, probably from mechanical suspension, in the water in which the parts of even delicate plants remained uninjured, the sand being more commonly forced along the bottom, and occasionally with the needful strength of stream or current to cut away the subjacent vegetable accumulations. Frequently also, silt, or sandy mud, was strewed over the future coal ground, the beds corresponding with its approximation to sand or mud, as the case might be, and the plants when found in it, being of a character, and exhibiting a preservation such as we might anticipate, according to the sandy or muddy state of the deposit.

In order to consider the manner in which the various sheets of gravel, sand, silt, mud, underbeds, and of vegetable matter constituting the coal measures, were accumulated in South Wales and South-Western England, we have, in imagination, to unite the various patches of coal measures, now separated by the great movements these and subjacent accumulations have undergone, and by the removal, from denudation, of the intermediate portions, massive as they must have been.

Dr. Buckland and Mr. Conybeare long since (1822) pointed out that the coal districts of Somerset, Gloucestershire, Monmouthshire, and Glamorgan, "though apparently distinct and insulated, are yet connected together by resting on a common base of old red sandstone. They all," it is remarked, "appear to have been formed by similar agency, and at the same era; to have been subject, at a later period, to the same revolutions; and, lastly, have been covered partially by similar overlying deposits." * The same geologists, to whose labours so much is due, divided the Bristol coal field, in the ascending order, into (1) millstone grit, (2) lower coal shale, (3) pennant grit, and (4) upper coal shale, and it will be desirable to observe how far and under what modifications these chief divisions may be carried out.†

The hard sandstones and conglomerates of the first division, with the shales occasionally associated with them, as also the Gower black shale beds, have been already noticed. In the Gower district, we have sandstones above the black shales, some light-coloured, which may be referred probably to the same date as part of this Farewell rock series.‡ Above these hard sandstones and associated beds, or their equivalents,

* Observations on the South-Western Coal District of England, Geological Transactions, Second Series, vol. i. p. 210.

† Ibid., p. 252. Numerous sections are given, p. 264, &c.

‡ See Vertical Sections of the Geological Survey of Great Britain, sheet 6, which illustrates the horizontal sections; sheet 9, section 1.

occurs that mass of beds so rich in coal and iron, upon which the great iron works of South Wales and Monmouthshire have been established, the proximity of the carboniferons limestone being also of the greatest value to them.

On the west, where the coal measures of Pembrokeshire abut upon the sea in St. Bride's Bay, from the occurrence of faults (the coal measures of Nolton and Newgale are inlaid, as it were, by faults among the Silurian rocks), and the great contortions to which the strata have been subjected, the sequence of beds is not so clear and complete as is desirable. On the north of Newgale Sands, the coal measures are brought in, abutting against the older rocks of the district, by a fault, in the following manner:—

Fig. 14.

a a a, fine-grained micaceous purple and gray sandstone (beneath the fossiliferous Silurian rocks of the country); *b*, trap dyke, cutting through these beds; *c*, soft brown and gray sandstone (lowest part of the coal measures here visible), abutting against *a a a*, at the fault *h*, and succeeded by (*d*) striped dark and light gray sandstones, above which are (*e*) brown and gray grits. Above these occur (*f*) fine-grained conglomerates and coarse grits, succeeded by (*g*) gray and brown sandstone, with shale and thin-bedded sandstones.

It may be that these coal measure sandstones and conglomerates occupy the place of the farewell rock or millstone series, though this is not clear from the mode of occurrence of the faults, letting in the coal measures. Above them, however, is a coal-bearing argillaceous slate, with some argillaceous ironstone, which may, in part, represent the lower shales. Information was obtained that, in these beds, partially worked on the south of Eweston about sixty years since, there were four chief seams or beds of coal.* The strata dip at an angle of about 30°, so that, including the coal worked at Newgale,† there must be a

* The Eweston coals are said to be as follows:—

1. Careg Gallard vein (culm)	3 to 4 feet
2. Bright vein (good anthracite)	4 to 10 feet
3. David Williams' vein (culm)	2 to 10 feet
4. Triquart vein (good anthracite)	4 feet

† The following section of the coal measures between Newgale Sands and Sibbernock Hill, in descending order, was obtained from Mr. David Walters, the workings being nearly abandoned, while the survey was in progress in that district.

		Ft.	In.
1. Sibbernock veins, two small beds of coal, about 23 yards apart			
Distance		240	0
2. Foot vein		1	0
Distance		150	0
3. Yard vein	varies from 1 foot to	4	0
Distance,		30	0

considerable thickness of the lower beds in this direction, assuming them to be equivalent to the lower shales to be hereafter noticed—one which, allowing for difference of dips diminishing southwards, may be estimated at about 1200 feet.

Without a better knowledge than now exists of the amount of some known and some probable faults, a knowledge that future coal-workings may assist in obtaining, it would be hazardous to attempt the construction of a general section joining the Newgale beds with those of Nolton and Druson Haven. It may be that a portion of the higher ground belongs to the middle sandstone, or Pennant grit series. The rolled pieces of preconsolidated coal, and of ironstone found in it, remind us of the occurrence of similar water-worn pebbles of coal and ironstone, so commonly discovered in that series near Swansea and other places.*

		Ft.	In.
4. Stink, or Migrement vein	varies from 1 foot to	4	0
Distance		40	0
5. Five feet vein	varies from 10 inches to	6	
Distance			
6. Triquart vein	from 2 feet to	3	6
Distance			
7. Second northern vein	from 10 inches to	1	6
Distance		100	0
8. Throw vein		3	0

* The following is a section, in descending order, of the beds between Druson and Nolton, made by Mr. Williams:—

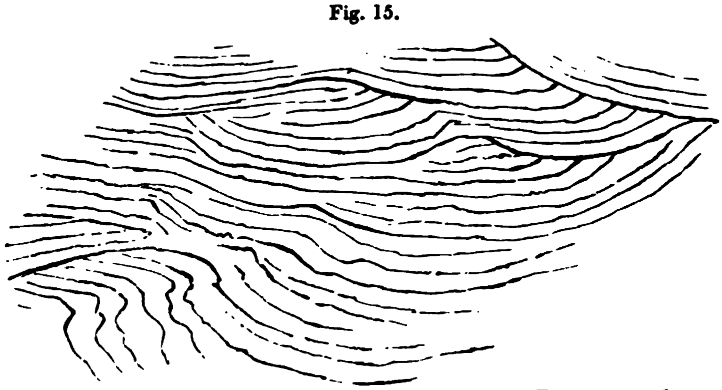
	Feet.
1. Gray sandstone	20
2. Shale	9
3. Sandstone, containing drifted nodules of ironstone	40
4. Shale	6
5. Irregularly-bedded sandstone	10
6. Shale and sandstone	4
7. Irregularly-bedded sandstone	68
8. Argillo-arenaceous shale	3
9. Sandstone	40
10. Hard arenaceous shale	6
11. Argillaceous shale	6
12. Hard sandstone	26
13. Gray micaceous sandstone	17
14. Gray argillaceous shale	13
15. Sandstone	6
16. Bed resembling underclay	3
17. Carbonaceous shale	1
18. Gray sandstone, containing drifted nodules of ironstone	22
19. Gray sandstone	
20. Sandstone, with comglomerate composed of drifted ironstone	54
21. Shale and sandstone alternating	4
22. Gray hard sandstone, containing rounded pebbles of coal	20
23. Sandstone and arenaceous shale	24

The following is the list of coal seams and beds, stated to be found at Nolton, in the descending order:—

	Ft.	In.
1. Black vein	1	6
2. Cliff vein	3	6

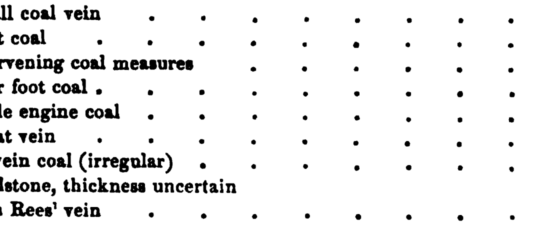
Among the sandstones there are some good examples of the irregularly accumulated sands, producing false bedding; and the coast is favourable for exhibiting the manner in which, on the upper side of a bed, amid numerous ripple marks or friction furrows, one layer of sand has been drifted horizontally over another. The following sketch by Professor Phillips exhibits a good instance of this fact near Nolton Haven.

Fig. 15.



The same line of coast, extending to Goultrop Roads on the south, where trap rocks are pressed against contorted coal measures, having overrun the small portion of carboniferous limestone there visible beneath it, exhibits many examples of irregular accumulation. The sketch beneath (Fig. 16) of part of the cliff between Little Haven and Goultrop Road, may be selected as showing that after the deposit of the lower mud or shale (*a*, *a*), a kind of hole or furrow was made in it (in the prolongation of *b*), into which sand was drifted, the whole

Fig. 16.



		Ft.	In.
3.	Small coal vein	1	4
4.	Foot coal	1	0
	Intervening coal measures	276	0
5.	Four foot coal	4	0
6.	Little engine coal	2	0
7.	Great vein	9	0
8.	Pit vein coal (irregular)	2	0
	Sandstone, thickness uncertain		
9.	Tom Rees' vein	1	6
10.	Smith coal vein	1	4

covered up by additional mud. Subsequently the mud was cut away (on the left), the lines of deposit shown by the lines of lamination, and sand was drifted against it, layer covering layer. After a time this ceased, and the mud, *d*, *d*, overspread the whole.

Instances of irregular deposit are very frequ ent in the coalmeasures of South Wales, and an unconformable position of parts from an upturned condition of strata, anterior to the deposit of higher beds, might often be hastily inferred from sections of the irregular accumulation of the beds, particularly among contortions.

The section south from Haverfordwest gives us a thin trace of carboniferous limestone, and beds of the hard sandstones of the farewell rock series above it; and we thus have no difficulty in seeing that the various anthracite beds, worked between Haverfordwest and Clareston, belong to the lower shales.*

The sections afforded by the continuation of Milford Haven towards Picton Castle and Slebech show a like succession, and these, taken with the coast section north of Tenby, by Sandersfoot, in Caermarthen Bay, would appear to give us little else than the lower shales, with their accompanying sandstones, for this part of Pembrokeshire. The following section seen in the cliffs between Wiseman's Bridge and the carboniferous limestone on the north, in company with Mr. Williams, will exhibit the mode of occurrence of the lower part of these beds, and the large amount of ironstone contained in them.†

Section of the Coal Measures between Wiseman's Bridge and Gilman Point, Pembrokeshire.‡

	Ft.	In.
1. Sandstone	6	0
*2. Argillaceous shale, with bands of ironstone	6	0
3. Sandstone	2	6
4. Argillaceous shale	6	0
5. Sandstone	2	4
6. Arenaceous shale	2	8
7. Sandstone	0	8
8. Arenaceous shale	15	0
*9. Slaty sandstone, with nodules of ironstone	4	6
10. Slaty sandstone	4	0

* See Horizontal Sections of the Geological Survey of Great Britain, sheet 1, section 2.

† A general view of the coal measures of the Tenby and Sandersfoot coast will be seen by reference to the Horizontal Sections of the Geological Survey of Great Britain, sheet 2, section 1.

‡ These and the other sections of the coal measures given in this memoir are intended merely to illustrate the subject geologically, although some of them may also be useful for economic purposes. For the latter object, the Vertical Sections of the Geological Survey of Great Britain, enumerated in the note, p. 148, will be found available, and others will be given when the economic value of the coal districts of South Wales and South Western England shall be pointed out in a subsequent volume of these memoirs.

	Ft.	In.
11. Sandstone and arenaceous shale	18	0
12. Sandstone	26	0
13. Argillaceous shale	6	0
*14. Arenaceous shale, with nodules of ironstone	1	8
15. Sandstone	6	0
*16. Arenaceous shale, with bands of ironstone	4	8
17. Sandstone	15	0
18. COAL	0	10
19. *Hard arenaceous underclay* (Stigmaria)	3	6
*20. Arenaceous shale, with ironstone	10	0
21. COAL (traces)		
22. *Underclay*	3	0
23. Sandstone	6	0
*24. Ironstone	0	2
25. Sandstone	2	3
*26. Ironstone	0	3
27. Sandstone	6	6
28. COAL	0	6
*29. *Underclay*, with nodules of ironstone in the lower part (Stigmaria)	6	6
*30. Ironstone	0	2
31. Argillaceous shale	1	0
*32. Ironstone	0	2
33. Argillaceous shale	0	10
*34. Ironstone	0	2
35. Argillaceous shale	1	0
36. Arenaceous shale	1	0
37. Arenaceous shale and sandstone	0	10
38. Arenaceous shale	1	0
*39. Ironstone	0	2
40. Arenaceous shale	1	3
*41. Ironstone	0	2
42. Arenaceous shale	4	0
*43. *Fireclay*, with ironstone (Stigmaria)	4	0
44. Arenaceous shale	7	6
45. Sandstone	1	0
46. Arenaceous shale	2	0
47. Sandstone	1	3
*48. Nodules of ironstone	0	6
49. Arenaceous shale	1	6
*50. Ironstone	0	5
51. Argillaceous shale	0	9
52. Sandstone	0	6
53. Argillaceous shale	0	6
54. Sandstone	0	4
55. Argillaceous shale	1	8
*56. Ironstone	0	5
*57. Argillaceous shale, with 3-inch bands of ironstone	6	0
58. Argillaceous shale	5	0
59. Hard sandstone	2	6
60. Argillaceous shale	0	4
61. Hard sandstone	3	0
62. Sandstone	3	0
*63. Nodules of ironstone	0	5
64. Hard arenaceous shale	2	4
*65. Ironstone	0	1

	Ft.	In.
66. Hard arenaceous shale	2	0
*67. Nodules of ironstone	0	3
68. Argillo-arenaceous shale	1	4
*69. Ironstone	0	1
70. Argillaceous shale	1	1
*71. Ironstone	0	1
72. Argillaceous shale	1	4
*73. Ironstone	0	1
74. Black argillaceous shale	1	8
*75. Ironstone	0	1
76. Argillaceous shale	2	0
*77. Ironstone	0	2
78. Hard sandstone	2	6
*79. Ironstone	0	2
80. Hard sandstone	3	0
81. Argillo-arenaceous shale	9	0
*82. Ironstone	0	3
83. Arenaceous shale	1	3
*84. Ironstone	0	3
85. Arenaceous shale	4	0
86. COAL		
87. *Underclay* (Stigmaria)	4	0
88. Argillaceous shale	7	0
89. Sandstone	4	0
90. Argillaceous shale	5	0
*91. Ironstone	0	1
92. Argillaceous shale	2	0
93. Sandstone	6	0
94. Arenaceous shale	2	6
*95. Ironstone	0	2
96. Argillaceous shale	2	0
*97. Ironstone	0	2
98. Argillaceous shale	1	0
*99. Ironstone	0	1
100. Argillaceous shale	1	6
*101. Ironstone	0	2
102. Argillaceous shale	2	6
*103. Ironstone	0	3
104. Argillaceous shale	1	8
*105. Ironstone	0	1
106. Argillaceous shale	10	0
107. COAL (traces)		
108. *Underclay* (Stigmaria)	3	0
109. Argillo-arenaceous shale	26	0
*110. Ironstone	0	2
*111. Argillo-arenaceous shale, with dispersed nodules of ironstone	13	0
112. Carbonaceous shale, with ANTHRACITE	1	6
113. *Underclay* (Stigmaria)	3	0
114. Sandstone, irregularly bedded	54	0
115. Argillaceous slate and sandstone	39	0
116. Arenaceous shale and sandstone	20	0
117. COAL (Rook's Nest)	3	0
118. *Underclay* (fireclay) (Stigmaria)	1	0
*119. Ironstone	0	2
120. Argillo-arenaceous shale	0	6
*121. Ironstone	0	2

	Ft.	In.
*122. Argillo-arenaceous shale, with nodules of ironstone	1	6
*123. Ironstone	0	2
*124. Argillo-arenaceous shale, with nodules of ironstone	2	0
125. Arenaceous shale	1	6
*126. Ironstone	0	2
127. Argillo-arenaceous shale	0	8
*128. Ironstone	0	1
129. Argillo-arenaceous shale	0	6
*130. Large nodules of inferior ironstone, termed *Jacks*	2	0
131. Argillaceous shale	0	6
*132. Ironstone	0	1
133. Argillaceous shale	0	4
*134. Ironstone	0	1
135. Argillaceous shale	0	4
*136. Ironstone	0	2
137. Argillaceous shale	1	0
*138. Ironstone	0	2
139. Argillaceous shale	0	10
*140. Ironstone	0	2
141. Argillaceous shale	1	0
*142. Ironstone	0	2
143. Argillaceous shale	0	7
*144. Ironstone	0	1
*145. Argillaceous shale, with thin seams of ironstone	2	0
*146. Argillaceous slate, with a seam of ironstone	4	0
*147. Ironstone	0	1
148. Coal (*thin crop*)		
149. *Underclay* (Stigmaria)	3	0
150. Hard sandstone	5	0
151. Schistose sandstone	2	0
*152. Ironstone	0	2
153. Hard arenaceous shale and sandstone		
154. Coal	0	4
155. Carbonaceous shale and coal	1	6
156. *Underclay* (Stigmaria)	3	0
*157. Ironstone	0	2
158. *Underclay* (Stigmaria)	0	6
*159. Ironstone	0	2
160. Argillaceous shale	0	8
*161. Ironstone	0	1
162. Argillaceous shale	0	8
*163. Ironstone	0	3
164. Hard arenaceous shale and sandstone	5	0
*165. Ironstone	0	1
166. Argillaceous shale	0	2
167. Hard sandstone	4	8
168. Coal and carbonaceous shale	2	6
169. *Underclay* (Stigmaria)	3	10
*170. Ironstone	0	10
*171. Argillaceous shale, with nodules of ironstone	3	6
*172. Argillaceous shale, with seams of ironstone	4	0
*173. Ironstone	0	3
*174. Arenaceous shale, with nodules of ironstone, *Vertical stems of Calamites*	3	0
175. Hard arenaceous shale	2	0
*176. Large nodules of inferior ironstone (*Jacks*)	2	0

		Ft.	In.
*177.	Arenaceous shale, with ironstone	4	0
*178.	Nodules of inferior ironstone (*Jacks*)	0	4
179.	Arenaceous shale	4	0
180.	Argillaceous shale	6	6
*181.	Nodules of ironstone	0	4
*182.	Argillaceous shale, with ironstone	4	0
183.	Coal	0	2
184.	*Underclay*, with ironstone (Stigmaria)	4	0
185.	Arenaceous shale	1	0
186.	Hard arenaceous shale	6	0
187.	Sandstone and arenaceous shale	7	0
188.	Arenaceous shale	3	0
189.	Coal (thin crop)		
190.	*Underclay*. The *Stigmaria ficoides* in this bed impregnated with ironstone, and 12 and more feet long	5	0
191.	Nodules of ironstone	0	9
192.	Arenaceous shale	3	6
193.	Argillo-arenaceous shale	2	6
*194.	Ironstone	0	2
195.	Argillo-arenaceous shale	3	0
*196.	Ironstone	0	1
*197.	Argillo-arenaceous shale, with ironstone	2	4
*198.	Nodules of ironstone	0	2
*199.	Argillaceous shale, with ironstone	3	0
200.	Sandstone	1	0
201.	Coal (thin crop)		
202.	*Underclay* (Stigmaria)	6	0
203.	Hard sandstone	7	6
204.	Argillaceous shale	0	2
*205.	Ironstone	0	2
206.	Arenaceous shale	2	0
207.	Sandstone	3	0
*208.	Ironstone	0	4
209.	Argillo-arenaceous shale	4	0
*210.	Ironstone	0	2
211.	Argillaceous shale	1	2
*212.	Ironstone	0	2
213.	Argillaceous shale	2	2
*214.	Ironstone	0	2
215.	Argillaceous shale	1	0
*216.	Ironstone	0	1
217.	Argillaceous shale	2	0
218.	Coal (Cat's Hole)	0	8
219.	*Underclay* (Fireclay) (Stigmaria)	3	0
220.	Arenaceous shale	6	0
*221.	Ironstone	0	2
222.	Arenaceous shale	2	0
*223.	Ironstone	0	1
224.	Arenaceous shale	1	10
*225.	Ironstone	0	3
226.	Arenaceous shale	3	6
*227.	Ironstone	0	3
228.	Arenaceous shale	2	10
*229.	Ironstone	0	1
230.	Argillaceous shale	0	4

		Ft.	In.
*231.	Ironstone	0	1
*232.	Argillaceous shale, with dispersed nodules of ironstone	5	0
233.	Coal and carbonaceous shale	0	8
234.	*Underclay* (Stigmaria)	2	0
235.	Sandstone	3	0
*236.	Arenaceous shale, containing nodules of ironstone	8	0
237.	Sandstone	5	0
238.	Hard arenaceous shale	1	0
*239.	Inferior ironstone (*Jacks*)	0	3
240.	Arenaceous shale	5	10
*241.	Ironstone	0	2
242.	Argillaceous shale	2	0
243.	Sandstone	5	6
*244.	Ironstone	0	2
245.	Arenaceous shale	5	0
*246.	Ironstone	0	3
*247.	Arenaceous shale, with nodules of ironstone	4	6
*248.	Ironstone	0	1
249.	Argillaceous shale	3	6
250.	Coal and carbonaceous shale	0	2
251.	Carbonaceous shale	0	7
*252.	Arenaceous shale, with nodules of ironstone	2	3
*253.	Ironstone	0	4
254.	Carbonaceous shale	1	0
255.	Coal and carbonaceous shale	0	4
256.	*Underclay* (Stigmaria)	0	10
357.	Sandstone	2	0
*258.	Hard arenaceous shale, with ironstone	3	4
259.	Sandstone	6	8
*260.	Argillo-arenaceous shale, with ironstone	7	0
261.	Hard standstone	2	8
*262.	Ironstone	0	2
263.	Argillo-arenaceous shale	3	0
*264.	Ironstone	0	1
265.	Argillo-arenaceous shale	6	6
*266.	Nodules of ironstone	0	5
267.	Argillaceous shale	1	6
*268.	Ironstone	0	1
269.	Argillaceous shale	1	6
*270.	Black argillaceous shale, with nodules of ironstone	7	0
271.	Coal (Tinker's Hill) crop only seen		
272.	*Underclay* (Stigmaria)	4	0
273.	Arenaceous shale	4	0
*274.	Argillo-arenaceous shale, with nodules of ironstone	5	6
275.	Sandstone	2	5
276.	Argillo-arenaceous shale	0	4
*277.	Ironstone	0	3
278.	Argillo-arenaceous shale	2	8
*279.	Ironstone	0	3
280.	Argillo-arenaceous shale	3	6
*281.	Ironstone	0	1
282.	Argillo-arenaceous shale	3	0
*283.	Ironstone	0	3
284.	Argillo-arenaceous shale	1	8
285.	Argillaceous shale	0	7

		Ft.	In.
*286.	Ironstone	0	1
*287.	Argillaceous shale, with nodules of ironstone	6	0
288.	Argillaceous limestone full of bivalves (*Unio ?*)	3	0
289.	Arenaceous shale	6	0
*290.	Argillaceous shale, with ironstone	25	0
291.	Shale and sandstone interstratified	71	0
292.	Hard sandstone	30	0
293.	COAL and carbonaceous shale, intermixed	4	0
294.	*Underclay* (Stigmaria)	3	5
295.	Argillo-arenaceous shale	7	0
*296.	Argillo-arenaceous shale, with ironstone	7	5
297.	Argillaceous and carbonaceous shale	4	0
298.	Sandstone	14	5
*299.	Argillaceous shale, with nodules of ironstone	5	0
300.	Argillaceous shale	3	0
*301.	Ironstone	0	2
302.	Argillaceous shale	3	6
*303.	Ironstone	0	2
304.	Argillaceous shale	1	4
*305.	Ironstone	0	2
306.	Argillaceous shale	0	5
*307.	Ironstone	0	2
308.	Argillaceous shale	4	0
*309.	Ironstone	0	2
310.	Argillaceous shale	1	0
*311.	Ironstone	0	1
312.	Argillaceous shale	2	5
*313.	Ironstone	0	1
314.	Argillaceous shale	3	0
*315.	Ironstone	0	2
316.	Argillaceous shale	18	0
*317.	Ironstone	0	5
318.	Argillaceous shale	12	0
*319.	Argillaceous shale, with a few nodules of ironstone	115	0
320.	Thin-bedded sandstone	6	
321.	Argillo-arenaceous shale	6	0
322.	Sandstone	0	8
323.	Argillo-arenaceous shale	20	0
324.	Thick-bedded sandstone	75	0
325.	COAL, a trace		
326.	Argillo-arenaceous shale, mixed with sandstone	3	0
327.	Hard sandstone	10	0
328.	Slaty sandstone	5	0
329.	Argillo-arenaceous shale	17	0
*330.	Ironstone	0	2
331.	Argillaceous shale	3	5
332.	Sandstone	0	7
333.	Argillo-arenaceous shale	1	5
334.	Sandstone	2	9
335.	Argillaceous shale	23	0
*336.	Ironstone	0	2
337.	Argillaceous shale	8	0
338.	Thin-bedded sandstone	10	0
*339.	Ironstone	0	2
340.	Argillaceous shale	9	0

	Ft.	In.
341. Hard sandstone	2	5
342. Argillaceous shale	7	0
343. Argillo-arenaceous shale, with 5 inches of sandstone	2	0
344. Argillaceous shale	4	0
345. Hard sandstone	0	5
*346. Argillaceous shale, with dispersed nodules of ironstone	4	5
347. Arenaceous shale	3	0
348. Hard sandstone	2	0
349. Flaggy and slaty sandstone	52	3
350. Argillo-arenaceous shale	12	5
*351. Ironstone	0	1½
352. Argillaceous shale	6	5
*353. Ironstone	0	1
354. Argillaceous shale	44	0
*355. Irregular nodules of ironstone		
356. Argillaceous shale	2	0
*357. Carbonaceous shale, with ironstone	1	0
358. Argillaceous shale	3	0
*359. Ironstone	0	2
360. Argillaceous shale	12	0
*361. Ironstone		2
*362. Argillaceous shale, with dispersed nodules of ironstone	4	0
363. Flaggy sandstone	9	5
364. Hard sandstone	6	0
*365. Argillaceous shale, with ironstone	7	0
366. Sandstone and arenaceous shale	7	6
*367. Ironstone	0	5
368. Arenaceous shale	5	5
*369. Ironstone	0	2
370. Argillaceous shale	2	9
*371. Irregular seam of ironstone	0	2
372. Argillo-arenaceous shale	9	0
*373. Ironstone	0	2
374. Argillo-arenaceous shale	27	7
*375. Argillaceous shale, with ironstone	23	10
*376. Argillaceous shale, with nodules of ironstone in the middle	14	5
377. Argillaceous shale	28	0
378. Argillo-arenaceous shale, with beds of sandstone	107	0
379. Black argillaceous shale	78	0
380. Hard quartzose sandstone (*Farewell Rock*)	70	0
381. Argillaceous shale	40	0
382. Hard quartzose sandstone (*Farewell Rock*)	30	0
383. Carboniferous limestone	300	0

Crossing over to the eastern side of Caermarthen Bay, the lower coal measure shales can be afterwards traced round the coal field of Caermarthenshire, Brecknockshire, Glamorganshire, and Monmouthshire, occupying a marked band, always known for the abundance of coal and ironstone in it. The maps and large horizontal and vertical sections of the Geological Survey will best illustrate the general mode of occurrence and detail of these beds.* Though replete with nodules

* Horizontal Sections, sheets 7, 8, 9, 10, 11, and 12; and Vertical Sections, 1, 2, 3, 4, 5, 6, 7, 8, and 9.

and thin beds of the impure carbonate of iron, known as clay ironstone, and full of valuable beds of coal, more or less extensively worked, the former would appear to increase in abundance towards the west. The amount of them seen in any good section at Cwm Ammon is very considerable. The general mass of these lower shales increases also in the same direction, without, however, any very marked increase in the amount of workable seams of coal. The decrease in the general thickness of these deposits is very obvious proceeding from the vicinity of Merthyr Tydfil to Pontypool.* The following sections will illustrate this fact:—

Section of the Lower Coal Measures at Plymouth Iron Works, Merthyr Tydfil.

		Ft.	In.
1.	Dark gray sandstone	6	0
2.	COAL	1	0
3.	*Underclay (good fireclay)*	6	0
4.	Gray argillaceous shale	4	0
*5.	Ironstone	0	2
6.	Gray argillaceous shale	4	0
7.	Arenaceous shale.	27	0
8.	Dark gray sandstone	1	0
9.	COAL, containing iron pyrites	1	6
10.	Carbonaceous shale	0	6
11.	*Underclay*	1	3
12.	COAL, mixed with carbonaceous shale	0	7
13.	Brown shale	0	3
14.	*Underclay*, light gray	0	10
15.	Argillaceous shale, blue gray	5	0
*16.	Ironstone (Top Vein)	0	3
17.	Argillaceous shale	2	0
*18.	Ironstone	0	0½
19.	Argillaceous shale	1	11
*20.	Ironstone	0	1
21.	Argillaceous shale	2	0
*22.	Ironstone (Bottom Vein)	0	2
23.	Argillaceous shale	3	0
24.	COAL	1	8
25.	Argillaceous shale (*underclay* at top)	39	0
26.	Dark gray arenaceous shale	57	0
27.	Soft brown sandstone, in which are numerous fissures filled with clay	10	0
28.	Carbonaceous shale and coal	0	9
29.	Soft brown sandstone, same as No. 27 — Black Pins	13	0
30.	Argillaceous and carbonaceous shale — Black Pins	2	0
*31.	Ironstone (Upper Rough Pin) — Black Pins	0	2
32.	Black argillaceous shale — Black Pins	3	0
*33.	Ironstone (Lower Rough Pin) — Black Pins	0	3
34.	Black argillaceous shale — Black Pins	3	0
35.	Ironstone (Top Pin) — Black Pins	0	3

* Vertical Sections, sheet 9.

		Ft.	In.
36. Black argillaceous shale	Black Pins	1	4
*37. Ironstone (Gray Pin)	Black Pins	0	3
38. Black argillaceous Shale	Black Pins	2	7
*39. Ironstone (Yellow Pin)		0	2¼
40. Brown argillaceous shale		0	10
*41. Ironstone (Bottom Pin)		0	1½
42. Dark gray argillaceous shale		3	0
*43. Ironstone		0	2
44. Blue gray argillaceous shale		2	6
*45. Ironstone		0	1
46. Argillo-arenaceous shale (probably)		25	8
47. Dark gray sandstone		2	0
*48. Ironstone		0	3
49. Gray argillaceous shale		2	6
*50. Ironstone		0	6
51. Bluish gray argillaceous shale		4	0
*52. Ironstone		0	4
53. Dark gray argillaceous shale		3	0
*54. Ironstone		0	6
55. Dark gray argillaceous shale		9	0
*56. Ironstone		0	6
57. Dark gray argillaceous shale		2	0
58. COAL		0	4
*59. *Underclay* and shale, containing small nodules of ironstone		9	0
*60. Argillaceous shale, containing ironstone irregularly		6	0
61. Argillaceous shale		3	0
*62. Ironstone		0	8
63. Dark gray argillaceous shale		15	0
64. Carbonaceous shale		0	4
65. COAL		0	7
66. *Arenaceous underclay*		2	11
67. Black shale and COAL		0	6
68. Carbonaceous shale		0	8
69. COAL		0	11
70. Carbonaceous shale, with COAL		0	6
71. COAL (Yard Vein)		2	3
72. *Underclay*		3	0
*73. Ironstone		0	6
74. Argillaceous shale		4	0
*75. Ironstone		0	4
76. Sandstone		10	2
*77. Ironstone nodules		0	6
78. Gray shale		2	6
*79. Ironstone		0	6
80. Gray shale		3	0
81. COAL (Upper Four Feet Vein)		4	0
82. *Underclay*		1	0
*83. Arenaceous shale, containing nodules of ironstone		14	0
84. COAL		1	0
*85. *Underclay*, beneath which arenaceous shale, containing dispersed nodules of ironstone		25	6
86. COAL		0	6
87. *Arenaceous underclay*		1	0
*88. Ironstone		0	4
89. Blue gray arenacous shale		5	0

		Ft.	In.
*90.	Ironstone	0	5
91.	Blue gray arenaceous shale	3	0
*92.	Ironstone	0	3
93.	Blue gray arenaceous shale	5	0
*94.	Ironstone nodules	0	5
95.	COAL (Plymouth Top Coal)	4	0
96.	Carbonaceous shales	2	0
97.	COAL (Bottom Coal)	4	0
*98.	*Underclay*, containing nodules of ironstone	8	11
99.	Dark brown arenaceous shale	6	0
100.	COAL	0	2
101.	Carbonaceous shale	0	7
102.	COAL	0	6
103.	*Underclay*	1	5
104.	COAL	0	6
105.	Carbonaceous shale	1	5
106.	COAL	0	3
*107.	*Underclay*, containing small nodules of ironstone	6	5
108.	Sandstone	1	0
109.	Argillaceous shale	3	3
110.	Arenaceous shale	3	0
111.	Sandstone	1	3
112.	Arenaceous shale	1	3
*113.	Brown argillaceous shale, containing small nodules of ironstone	4	6
114.	Brown argillaceous shale	2	2
115.	COAL	0	5
*116.	*Underclay*, containing numerous small nodules of ironstone	4	4
117.	Sandstone	7	6
118.	Gray argillaceous shale	2	0
*119.	Ironstone	0	4
120.	Gray argillaceous shale	4	0
121.	Sandstone	0	6
*122.	Argillaceous shale, containing numerous small nodules of ironstone	7	7
123.	Dark gray argillaceous shale	5	4
*124.	Ironstone	0	1½
125.	Gray argillaceous shale	0	4½
*126.	Ironstone	0	1
127.	Gray argillaceous shale	3	2
128.	Carbonaceous shale	3	9
129.	Argillaceous shale	3	6
*130.	Ironstone nodules	0	6
131.	Argillaceous shale	4	0
*132.	Ironstone	0	3
133.	Gray argillaceous shale	2	5
*134.	Ironstone	0	2½
135.	Dark brown argillaceous shale	4	5
136.	COAL	0	3½
137.	Carbonaceous shale	1	0
138.	COAL	0	4
139.	Carbonaceous shale	2	9
140.	COAL (Red Vein)	3	4
141.	*Underclay*	1	6
142.	Arenaceous shale	6	1
*143.	Ironstone nodules	0	6
144.	Dark brown arenaceous shale	3	3

	Ft.	In.
*145. Ironstone	0	9
146. Dark brown arenaceous shale	5	6
*147. Ironstone	0	6
148. Arenaceous shale	6	0
149. COAL	1	8
150. Iron pyrites	0	2
151. COAL (with No. 149, the Raslas, or Nine Feet Vein)	6	2
152. *Underclay*	1	2
153. Arenaceous shale	3	0
154. COAL (Brass Vein)	3	2
*155. *Underclay*, containing nodules of ironstone	2	8
156. *Underclay* (fireclay)	4	0
157. Arenaceous shale	5	0
*158. Ironstone	0	1½
159. Argillaceous shale	1	2
*160. Ironstone	0	2
161. Argillaceous shale	0	3
*162. Ironstone	0	2
163. Argillaceous shale	2	11
*164. Ironstone	0	2½
*165. Argillaceous shale, containing nodules of ironstone	11	0
*166. Dark argillaceous shale	0	9
*167. Ironstone	0	6
168. Argillaceous shale	0	9
*169. Argillaceous shale, containing small nodules of ironstone	10	6
*170. Ironstone	0	2
*171. Arenaceous shale, containing dispersed nodules of ironstone	20	10
172. Sandstone	0	4
173. Arenaceous shale	0	3
174. Sandstone	2	0
175. Arenaceous shale	0	8
176. Sandstone	2	3
177. Arenaceous shale	3	0
178. Sandstone	3	2
179. Arenaceous shale	16	6
180. Sandstone	1	3
181. COAL, and carbonaceous shale	0	4
182. Sandstone	5	6
*183. Argillaceous shale, containing nodules of ironstone	6	0
*184. Argillo-arenaceous shale, with dispersed nodules of ironstone	21	4
185. COAL, and carbonaceous shale	0	4
186. *Underclay*, good fireclay	4	2
187. Arenaceous shale	2	3
188. Sandstone	1	0
*189. Ironstone	0	4
190. Arenaceous shale	1	9
191. Sandstone	0	3½
192. Arenaceous shale	0	11½
193. Sandstone	0	3
194. Argillaceous shale	5	0
195. COAL	1	8
196. Carbonaceous shale	0	4
197. COAL	1	1½
198. COAL and *underclay*, mixed	1	2
199. Arenaceous shale, with a few beds of sandstone	10	3

		Ft.	In.
200.	Argillaceous shale	0	4
*201.	Ironstone	0	4
202.	Argillaceous shale	1	11
203.	Carbonaceous shale	0	6
204.	Coal	1	10
205.	*Underclay* (?)*		
*206.	Arenaceous shale, containing a few nodules of ironstone	11	5
207.	Coal	1	7
208.	Carbonaceous shale	0	6
209.	Coal	0	7
210.	Argillaceous shale, mixed with iron pyrites	0	5
*211.	Arenaceous shale, with nodules of ironstone	6	0
212.	Coal (Lower Four Feet Vein)	2	2
213.	Carbonaceous shale	0	3
214.	*Underclay*	2	9
*215.	Argillaceous shale, containing numerous small nodules of ironstone	4	0
*216.	Arenaceous shale, containing large nodules of ironstone	8	6
217.	Sandstone	2	0
218.	Blue gray argillaceous shale	2	8
*219.	Ironstone (Large Vein)	0	3½
220.	Blue gray argillaceous shale	1	3
*221.	Ironstone (Little Vein)	0	3½
222.	Blue gray argillaceous shale	3	5
*223.	Ironstone (Holing Pin)	0	1
224.	Argillaceous shale	2	7
*225.	Ironstone (Black Pin)	0	4
226.	Black rider, in argillaceous shale	0	10
227.	Black carbonaceous shale	0	2
228.	Black argillaceous shale	1	7
229.	Carbonaceous shale	0	1
230.	Black arenaceous shale	1	0
231.	Dark gray sandstone	15	0
232.	Blue gray argillaceous shale	2	0
*233.	Ironstone (Top Vein)	0	4
234.	Blue argillaceous shale	3	2
*235.	Ironstone (Holing Pin)	0	0½
236.	Blue gray argillaceous shale	1	10
*237.	Ironstone (Bottom Vein)	0	2½
238.	Blue gray arenaceous shale	3	2
*239.	Black argillaceous shale, containing nodules of ironstone (3 inches) called Black Vein	4	1
240.	Argillaceous shale	3	5
*241.	Ironstone (Stone Vein)	0	3
242.	Dark gray argillaceous shale	1	3
*243.	Ironstone (Jack Vein)	0	3
244.	Dark gray argillaceous shale	1	7
*245.	Ironstone (Rolling Pin)	0	1
246.	Argillaceous shale	2	3
*247.	Ironstone (Spotted Vein)	0	0½

* In sections which have been much taken from mining documents, such as this has chiefly been, in which the underclays are so rarely viewed in a geological manner, there is reason to conclude that, in accordance with the facts observed in connexion with all the coal beds, studied for that purpose in the vicinity, there really is some modification of a Stigmaria bed beneath the coal, No. 204.

	Ft.	In.
248. Black argillaceous shale	2	0
*249. Ironstone (Henry's Pin)	0	2½
250. Dark gray argillaceous shale	1	6
251. Arenaceous shale	5	7
*252. Ironstone (Big Vein)	0	4
253. Argillaceous shale	4	2
*254. Ironstone (Tobacco Pin)	0	1½
255. Blue gray argillaceous shale	3	0
*256. Ironstone (Double Nobbed Pin)	0	2½
257. Argillaceous shale	0	11
*258. Ironstone (Little Vein)	0	2
259. Blue gray argillaceous shale	3	0
*260. Ironstone (Lower Pin)	0	2
261. Dark blue argillaceous shale	3	0
*262. Ironstone (Rough Pin)	0	3
263. Dark blue argillaceous shale	1	9
264. Coal (Bottom Little Vein)	0	9
265. *Underclay* (good fireclay)	1	3
266. Sandstone, named Little Farewell Rock		

Section of the Lower Shales, Pont y pool, Monmouthshire.

	Ft.	In.
1. Gray argillaceous shale	8	0
2. *Fireclay*	8	6
3. COAL	1	0
4. Sandstone	2	0
5. COAL	2	0
6. Hard siliceous *underbed* with Stigmaria	19	0
*7. Soft shale, containing four courses of ironstone (Black Pins)	12	0
8. *Fireclay*	3	0
9. Argillaceous shale	4	0
10. Sandstone	2	6
11. Argillaceous shale	51	0
12. COAL (New Vein)	4	0
13. *Underclay*	4	0
*14. Argillaceous shale, containing nodules of ironstone	9	0
*15. Argillaceous shale, with three courses of ironstone	3	0
16. Carbonaceous shale	0	6
17. COAL	0	6
18. Clay parting	0	2
*19. *Underclay*, containing ironstone nodules	6	0
20. COAL (Troideg)	2	0
21. Parting	0	2
22. COAL	1	10
23. *Underclay*	3	6
24. Black shale	6	0
25. Hard arenaceous shale	3	0
*26. Argillaceous shale, containing nodules of ironstone (Red Vein Balls)	6	0
27. COAL	0	2
28. Shale parting	0	10
29. COAL (Red Vein)	2	6
30. Black shale	1	0
31. COAL	0	8
32. Carbonaceous shale and COAL	1	0
33. COAL	0	2

	Ft.	In.
34. Carbonaceous shale	1	4
35. COAL	0	8
36. *Hard Underclay*	6	0
37. Hard gray shale	6	0
38. Sandstone	1	0
*39. Hard shale with ironstone	5	0
40. Hard arenaceous shale	1	0
*41. Shale containing nodules of ironstone (Rock Vein Balls)	8	4
42. COAL (Rock Vein)	8	0
43. *Underclay*	2	11
44. Carbonaceous shale	2	0
45. *Underclay*	2	0
46. Black slaty shale	2	0
*47. Hard argillaceous shale with ironstone	6	0
48. Black slaty shale	2	0
*49. Hard shale, with two courses of ironstone	9	6
*50. Soft shale with ironstone nodules	2	6
51. Carbonaceous shale	1	0
52. COAL	0	6
53. *Underclay*	2	0
54. COAL	0	2
55. *Underclay*	2	0
56. COAL (Yard Vein)	2	8
57. *Underclay*	2	0
*58. Hard shale, with nodules of ironstone	2	0
59. COAL (John Williams' Vein)	1	0
60. Carbonaceous shale	1	0
61. *Underclay*	2	6
*62. Shale, with nodules of ironstone	3	0
63. Sandstone	1	6
*64. Shale containing nodules of ironstone (Meadow Vein Balls)	8	4
*65. Argillaceous shale containing two courses of ironstone	1	7
*66. Nodules of ironstone	0	2
*67. Shale containing large nodules of ironstone	4	0
68. Argillaceous shale	2	6
*69. Nodules of ironstone	0	3
70. Argillaceous shale	17	0
71. COAL	1	11
72. Parting	0	6
73. COAL (Meadow Vein)	4	0
74. Carbonaceous shale	0	4
75. CANNEL COAL	0	6
76. Carbonaceous shale	0	3
77. COAL	2	0
78. *Underclay*	3	0
79. Yellow sandstone	8	6
80. Argillaceous shale	1	0
81. COAL 1ft. 6in.; 82. Carb. shale 1 0; 83. COAL 2 6 } Stone Vein	5	0
84. *Underclay*	1	6
85. Hard sandstone	18	0
86. Argillaceous shale	2	0
87. Hard sandstone	4	6
*88. Argillaceous shale, with two bands of ironstone (10 in.)	7	2

		Ft.	In.
*89.	Argillaceous shale, with inferior ironstone	4	6
90.	Carbonaceous shale and COAL	1	0
91.	*Hard Underclay*	2	0
92.	Hard sandstone	22	0
93.	Argillaceous shale	1	6
94.	White compact sandstone	13	6
95.	Conglomerate	7	0
*96.	Argillaceous shale, with two seams of ironstone (1 ft.)	12	0
97.	COAL (Little Coal)	1	6
98.	*Underclay* (Fireclay)	2	0
99.	Hard sandstone (Farewell Rock)	68	0
*100.	Argillaceous shale, with inferior ironstone	40	0
101.	Hard sandstone (Farewell Rock)	50	0
102.	Yellow marl	4	0
103.	Carboniferous limestone	518	0

By comparing these sections, we find that there has been a decrease of general thickness between Merthyr Tydfil and Pont y pool of about 390 feet, the Plymouth Works section giving a depth of 812 feet, and the Pont y pool section one of 423 feet. This, though apparently a considerable decrease in general thickness for a distance of about 15 miles, would appear a level, if exposed to view, since the angle would be scarcely appreciable, being only a decrease of 1 in 203, a slight gradient for a railway.

Passing southward from Pont y pool, and then westward to the section afforded by the Taffe, above Cardiff,* we observe the same general characters for the lower shales. The following section, by Mr. Lewis Williams, of the lower coal measures at Cefn Crebwr, north-westward of Bridgend, will show the mode of occurrence of the lower shales in that direction.

Section of the Coal Measures near Cefn Crebwr, Glamorganshire.

		Ft.	In.
1.	Shale	2	0
2.	COAL	1	6
3.	Parting of clod	0	6
4.	COAL	1	6
5.	*Underclay*	1	0
6.	Shale	181	0
7.	COAL (Bridge Vein)	2	3
*8.	*Underclay*, with nodules of ironstone	12	0
9.	COAL (Lower Bridge Vein)	2	6
10. 11.	*Underclay*, thickness not given, but with Shale, beneath.	112	0
12.	COAL (Lantern)	5	0
13. *14.	*Underclay*, thickness not stated, but with Shale, containing nodules of ironstone	180	0
15.	COAL (Small Rotten, or Bodder Vein)	5	0
16.	*Underclay* (fireclay)	2	0
17.	Shale	4	0

* Sections of the Geological Survey of Great Britain, sheet 11.

		Ft.	In.
*18.	Seam of ironstone (technically Pin of Mine)	0	3
19.	Shale	10	0
*20.	Shale, containing five ironstone seams, collectively = 11 inches	14	0
21.	Black argillaceous shale	26	0
22.	Soft blue argillaceous shale	20	0
23.	Sandstone	28	0
24.	Argillaceous shale	6	0
25.	COAL (Great Bodder or Rotten)	7	6
26.	*Underclay* (Fireclay)	3	0
27.	Argillo-arenaceous shale	26	0
28.	COAL (Sooty)	6	0
29.	*Underclay*	2	6
30.	Soft argillaceous shale	68	0
*31.	Seam of ironstone	0	2
32.	Shale	3	0
*33.	Seam of ironstone	0	3
34.	Shale	5	3
35.	COAL (North fawr)	10	0
36.	*Underclay*	2	
37.	Hard arenaceous shale	36	0
*38.	Nodules of ironstone	0	3
39.	COAL (South fawr)	4	0
40.	*Underclay*	3	0
*41.	Nodules of ironstone	0	3
42.	Soft argillaceous shale	20	0
43.	COAL (Second)	4	0
44.	*Underclay*	2	0
45.	Blue argillaceous shale	33	6
*46.	Seam of ironstone	0	2
47.	Shale	3	6
*48.	Seam of ironstone	0	2
49.	Blue shale	12	6
50.	COAL (Third)	5	0
51.	*Underclay*	2	6
52.	Hard arenaceous shale	22	0
53.	COAL	1	0
54.	*Underclay*, thickness not stated, with	14	0
55.	Shale		
56.	COAL (Six Feet)	2	9
57.	*Underclay* ?*		
58.	Hard arenaceous shale	49	0
*59.	Seam of ironstone	0	3
60.	Shale	2	0
*61.	Seam of ironstone	0	3
62.	Shale	5	6
*63.	Seam of ironstone	0	3
64.	Shale	10	0
65.	COAL (Nine Feet)	9	0
*66.	*Underclay*, with nodules of ironstone and shale	22	10
67.	Sandstone	3	0
*68.	Shale, with a line of ironstone nodules	4	0
*69.	Seam of ironstone	0	5

* The underclay is found near at hand beneath this bed, and its omission above is common in mining coal sections.

		Ft.	In.
70.	Shale	20	0
*71.	Seam of ironstone	0	4
72.	Shale	8	0
*73.	Shale, with three seams of ironstone	5	0
74.	COAL	1	0
75.	Parting	1	0
76.	COAL (Bottom)	4	0
77.	*Underclay*, and arenaceous shale	17	0
78.	COAL	1	0
*79.	*Underclay*, and shale containing seams and nodules of ironstone	19	0
80.	Sandstone	18	0
81.	COAL (4 feet), } (Pimp Quart Vein)		
82.	Parting (2 feet), } (Pimp Quart Vein)	6	6
83.	Coal (6 inches), } (Pimp Quart Vein)		
84.	*Underclay*	3	0
85.	Shale	20	0
*86.	Seam of ironstone	0	3
87.	Argillaceous shale	2	0
88.	Sandstone	8	0
89.	Argillaceous shale	3	0
90.	COAL (Crybwr fawr Vein)	6	0
91.	*Underclay*	2	6
*92.	Shale, containing three lines of ironstone nodules	19	0
*93.	Shale, containing eight seams of spotted ironstone	16	0
94.	Shale	10	0
95.	COAL (Canel or Candle)	0	6
96.	Black carbonaceous shale	4	0
97.	Sandstone (Yellow Vein Rock)	5	6
*98.	Shale, containing the ironstone nodules known as the Yellow Balls	6	3
99.	Sandstone (Red Vein Rock)	9	0
*100.	Shale, containing seams and nodules of ironstone (Red Vein Balls and Pins)	13	0
*101.	Shale, containing the seams and nodules of ironstone known as the Double Balls, the Black Pins, and the Rhydw Balls	20	6
102.	Sandstone (Blue Vein Rock)	17	0
*103.	Shale, containing ironstone nodules (Blue Balls)	15	0
*104.	Shale, containing ironstone nodules (Lumpy Balls)	12	0
*105.	Shale, with a seam of ironstone (Pin Garw Mine)	11	6
106.	COAL (Crebwr fach)	2	6
107.	*Underclay*	1	6
108.	Sandstone	14	0
*109.	Shale, containing seams and nodules of ironstone	19	0
110.	Sandstone	22	0
111.	Soft shale	69	0
*112.	Shale, containing ironstone (Lower Red Vein)	8	0
113.	Blue Shale	216	0
*114.	Shale, containing ironstone (Southern Mine)	5	6

From the decrease of depth between Merthyr Tydfil and Pontypool it might be expected that the lower shales would be found less thick, or even disappear, in any patch or remains of coal measures which might occur to the eastward, in the line of this decrease. Accordingly, at Dean Forest, the lower shales, with their numerous beds of ironstone, seem to have disappeared, or have become greatly modified in character,

so that accumulations, more generally agreeing with the sandstones above them, there rest upon the Farewell Rock or millstone grit series.* In the Bristol coal district the lower shales, as defined by Dr. Buckland and Mr. Conybeare,† are well characterised by a large proportion of shale, as also apparently towards the Mendip Hills, the beds or nodules of ironstone being, however, but few compared with their occurrence in South Wales and Monmouthshire.

We thus attain a very unequal depth of a mass of mud, streaked with sands and beds of coal and underclay, thickest apparently to the westward, and fining off or altering its character north-eastward, at Dean Forest, but again regaining it, to a certain extent, on the south-east around Bristol.

As we have to consider it not improbable that the coal grew on the spot, that the vegetation of which it is composed was not subaqueous, at least not more so than in a peat bog, even supposing it grew in wet situations, and that it probably required contact with the atmosphere, conditions have to be sought very dissimilar to those producing the carboniferous limestone. Some of the vegetable accumulations must have been considerable, since we even find them, after the change and compression they have undergone, attaining a thickness of 15 feet, as, for instance, near Aberpergwm, Cwm Nedd, and very numerous beds of three feet and upwards are discovered and worked in the lower shales. Thus the sands, often so white and unmixed with coloured detritus, and spread over the wide area above noticed (p. 144), were now succeeded by mud deposits (sand drifts bearing a small proportion to the general mass), covering up vegetation that apparently grew on the spot at often-repeated intervals.

By the continued subsidence of a wide space, and the filling up of the depression by detritus covered by the growth of plants, when the conditions suited, in the general manner suggested by De Luc, we can obtain the accumulation observed. It is required that such subsidence and filling up took place in one part of a general area, sometimes so as to bring the sea and its inhabitants over part of it, as towards central and northern England, where coal beds, with underclays, sand, and common mud, are found associated with calcareous and fossiliferous deposits of the carboniferous limestone period, and, therefore, of an earlier date than the coal measures of South Wales and south-western England. This marks not only an earlier state of coal conditions on the north, but also a gradual

* The change of character of the Pontypool and Dean Forest coal measures will be observed by reference to the Horizontal Sections of the Geological Survey of Great Britain, sheet 12, and Vertical Sections, sheet 7, section 2, and sheet 10.

† Geological Transactions, second series, vol. i. p. 253. A section of the Bristol coal field is given among the Vertical Sections of the Geological Survey, sheet 11; and through part of it, in the Horizontal Sections, sheet 14, section 3.

slope of the sea bottom from thence southward. Taking the coal beds to requirel and, or something closely approaching to it, for their production, the sea bottom was sooner above water at the period of the carboniferous limestone on the north than on the south, and it was only after a lapse of the necessary geological time that the southern depression was fitted sufficiently for the growth of the plants that subsequently formed the coal.*

In the lower shales of our district there is evidence of much quiet accumulation. The only animal remains hitherto noticed in it would appear to be those shells which have been referred, though incorrectly it is now supposed, to the genus Unio. They were generally distributed, though in unequal numbers, over certain lower portions of the shales. How far these shells may be marine seems doubtful; but even supposing them to be such, traces of them are soon lost in the ascending series, and plants only are discovered in the thousands of feet which form the thickness of the subsequent coal-measure accumulations of the district. Some land, bearing the splendid vegetation, the partial remains of which we find entombed in the mud and sand of this period, would have to be abraded to furnish the detritus required. The plants and mud, with an occasional mixture of sand, seem to have been quietly borne onwards together over the space occupied by the vegetation growing on the spot, so that the kind of transport more reminds us of the swelling of vast rivers bearing the finer detritus brought to them from higher grounds and more rapid currents, and discharged over great plant-growing flats towards their embouchures, gradually subsiding, than any common lacustrine or marine deposits we now know.

A long line of flat coast, such as the eastern side of South America presents,† where great rivers emptied themselves, bringing down the detritus of higher grounds, and transporting even delicate plants and leaves, such as might fall into them, or the rising of their waters float away, would serve to explain the mud accumulations. From changes in the amount of subsidence, more at one time than at another, and more in one place than another, we should obtain a steeper fall with increased

* At some future time, when the details of the coal measures of the United Kingdom shall have become well known, and the connexion of one portion with another properly traced, it may be anticipated that a general view of the whole, with reference to the probability of the existence and form of land at the time of its production, and of the modification of circumstances necessary for the introduction of marine deposits amid its beds, will present us with a most interesting insight into the condition of this part of the world at a remote geological period.

† Mr. Lyell, describing the Great Dismal Swamp in Virginia, mentions, as illustrative of the origin of coal, that the vegetable mass composing this swamp covers the surface of a low level region bordering the sea for several square miles, and that it is capable of spreading still farther over the neighbouring country. Trees grow upon it; and he observes, that "Juniper trees, or white cedars *(Cupressus thyoides)*, stand firmly in the

velocity of current, and consequent power to transport heavier detritus, such as sand, more at one time than another, and more in one direction than another. Under the conditions apparently required for the accumulation of the general mass, we have in this district to exclude the sea, or at least such of its inhabitants as could live on or in the mud and sand supposed to be thus deposited, and to account also for the absence of river-born fresh-water animals, although more northerly in Great Britain there are well-known facts, which would require an intermixture of sea, with its inhabitants of the time, of fresh-water animals, and even of terrestrial creatures, such as insects,* with the deposits of the period.

When we attentively study the coal beds themselves in the lower shales of South Wales, for which the works upon them and the natural sections afford so many facilities, we see that many of them, though variable in thickness, can be traced for considerable distances, regarded relatively to the area occupied by the coal measures. Really large, however, as it may appear, when we regard any known portion of this area over which the same sheet of coal, crumpled as it may have been by undulations and contortions, and fractured by faults, can be traced, it becomes a minor patch of vegetable matter, when viewed with reference to the localities at the mouths of the great rivers of the present day, where, among the irregular accumulations, shallow lagoons and other slight depressions are to be found.

As no bed of coal has, when carefully examined in the south-western coal district, been found without its underbed containing Stigmariæ, surrounded by their divergent leaves or roots, as they may be, it scarcely can be doubted, that we see these plants in the ground in which they grew, and that this was soft ground, or a shallow muddy place, occupying spaces often of considerable area. Whether these Stigmariæ were the roots or stems of plants which subsequently grew above them, and were accumulated in broad sheets, or were merely the precursors of other plants which, when the needful conditions arose, grew upon the mud, sometimes sandy, penetrated by the Stigmariæ, we have vegetation co-extensive, commonly, with the peculiar bed beneath, such as there is no

soft part of the quagmire, supported by their long tap roots, and afford, with many other evergreens, a dark shade, under which a multitude of ferns, reeds, and shrubs, from nine to eighteen feet high spring up, and are protected from the rays of the sun." The soil of the swamp does not perfectly resemble the peat of Europe, but the plants are so decayed as to form black mud without traces of organization. Great trunks of trees are buried in the black mire, and there is a large lake in the centre of the swamp, which rises higher than the sides, as happens with many peat bogs, from the greater quantity of water there collected. Mr. Lyell points out the general resemblance of the upright trees above the swamp, and of the prostrate trees in it, to the trunks of *Sigillariæ*, *Lepidodendron*, and others, in the coal and to the erect stems of *Sigillariæ*, &c., above it.—Travels in North America, vol. i. p. 148. London, 1845.

* Coalbrook Dale.—Prestwich, Geol. Trans.; Brodie, Fossil Insects.

difficulty in supposing may have filled up slight cavities in the generally flat accumulations around and beneath them.

If it be objected that the rivers supposed would require large continents for their existence, of which we do not see the probable place, it should be observed that, from the mass of detritus composing the coal measures of this district only, with proper allowance for the great part of the original accumulations removed by denudation, the destruction of some large portion of land supporting a luxuriant vegetation would appear requisite, the terrestial plants mingled so plentifully with the mud and sand showing the kind of flora existing on such adjacent land. Every mountain formed of coal measures, of which there are so many in South Wales, requires an equal amount of land to be worn away, excepting so much as the comparatively small amount of vegetation it may entomb, and when we sum up the cubic miles of detritus alone required for the south-western coal measures of England and Wales. including the portion clearly removed by denudation, we have a mass of matter, which it would require no small superficial amount of land to furnish, by forces such as we now see in operation, within even a moderate lapse of geological time.

In reasoning upon the production of the coal measures, within this district at least, we can scarcely look to the action of sea-breakers for the abrasion of land required, nor to tides nor marine currents, for the transport of the detritus, since there are no marine remains mingled with them, and yet argillaceous shales are often for great depths free from carbonaceous matter which might be thought injurious to marine animal life,* and peroxide of iron is not mingled with them except in some minor localities. These shales and their accompanying sandstones are for the most part lithologically the same with those which at former geological times, and at subsequent periods, swarmed with marine life on and in them, so that there is no apparent reason of this kind why the remains of marine creatures should not be found in the lower shales of the south-western coal measures.

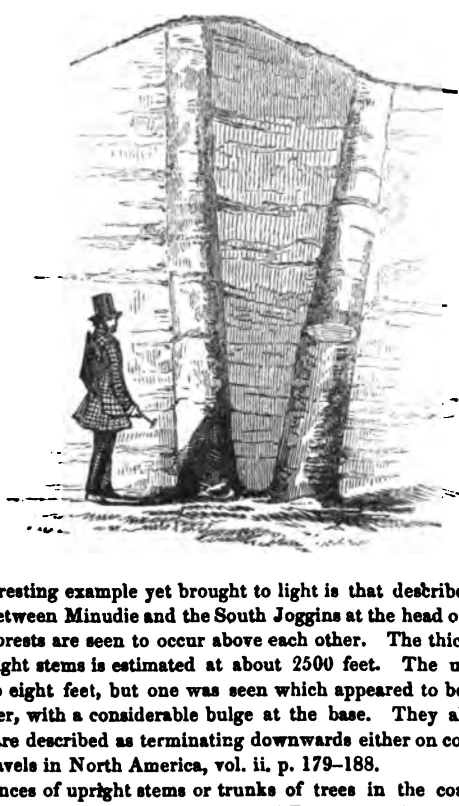
We arrive apparently, therefore, at the necessity of finding transporting waters not marine for the lower shales of the district. If we take great bodies of fresh water, such, for instance, as the great lakes of Northern America, with outflowing waters, and depress them by subsidence, so long as the outflowing waters are not driven back, the general conditions of the basin remain the same, and a mere filling up, much as if it continued undepressed, would be the result. So that by filling up such a cavity we do not appear to obtain the often repeated underbeds with

* Goniatites in carbonaceous shales show that black mud was not ill suited to them, as they are often discovered in such shales in multitudes, and in a manner tending to show that they lived upon the shale when it formed black mud.

their covering of vegetation, interstratified with transported mud, silt, sand, or gravel. When depressed so that the sea entered the cavity filled with fresh water, the heavier fluid would displace the lighter, and marine conditions would prevail.

That terrestrial vegetation did really exist while the coal measures were accumulating, and upon the very area upon which the mud and sand were deposited, we have now abundant proofs.* The evidence of this fact, at an early period during the formation of the lower shales, is well seen at Cwm Llech, towards the head of the Swansea valley, where, as has been noticed by Mr. Logan, a ravine cuts into a group of Sigillariæ.† Beneath is a sketch of two of these stems growing close to each other.

Fig. 17.



* The most interesting example yet brought to light is that described by Mr. Lyell as seen on the cliffs between Minudie and the South Joggins at the head of the Bay of Fundy, where ten buried forests are seen to occur above each other. The thickness of the beds containing the upright stems is estimated at about 2500 feet. The usual height of the trees is from six to eight feet, but one was seen which appeared to be 25 feet high, and four feet in diameter, with a considerable bulge at the base. They all appeared of the same species, and are described as terminating downwards either on coal or shale, but not on sandstone.—Travels in North America, vol. ii. p. 179–188.

Among the instances of upright stems or trunks of trees in the coal measures of our own country, those noticed by Mr. Hawkshaw and Bowman as found at the cutting of the Bolton Railway, at Dixonfield, is the most important, several trees of large size and near each other having been cleared out, so that we view them as trunks of trees standing where they grew.—Proceedings of the Geological Society, vol. iii. p. 139–270.

† Annual Report of the Royal Institution of South Wales, June, 1838, where a lithograph sketch of the upright Sigillariæ is given.

By carefully, in company with Mr. Logan, uncovering the shale upon which the Sigillariæ stood, coaly matter resembling roots was observed, without, however, presenting the appearance of Stigmariæ. The shale itself was full of fern leaves and other plants, crossing each other in all directions, as if fallen and distributed on a muddy ground. These stems, one of which rose to the height of thirteen feet, had as usual a coal bark, and were filled internally, as is also commonly the case, with drifted matter, as if the external parts had long remained firm, while the internal portions decayed, and were filled, as the sands were accumulated by the drift of the time.* Such a state of things appears to mark much tranquillity, for the stems, and there may have been a little forest of them, as they are seen erect as far as the beds containing them can be observed, could scarcely have resisted much pressure under such conditions. Studying the mode in which the sand was accumulated round the stems, in order to trace, if possible, the direction whence the drift came against them, little was observed to mark an eddy caused by the action of a rapid current upon them, at the same time that the laminæ of the sandstone were slightly raised towards the stems, as if washed against them by small waves in shallow water. The largest stem was five feet six inches in circumference.†

Beneath the shale which appears to have supported the growth of the Sigillaria stems at Cwm Llech, there is a small coal seam. If we regard the truncated stems of Sigillariæ above many a coal bed, leaving spaces known as *pot-holes*, and often so dangerous, by their falling, to the miners, as stems standing where they grew, the tops having soon rotted off, or the sands or silt not having covered them over soon enough to preserve much of the plant from decay, there must be many an instance of Sigillaria forests, growing in soft ground immediately above the vegetation from which the coal has been formed.

While pointing out this fact, and taking the same view of the subject, Dr. Buckland observes, that "the occasional assemblage of large numbers of cones and seed vessels of the same species, *e. g.*, of Lepidostrobus and Trigonocarpum, upon one spot, seems to indicate that they dropped into their present place from the trees on which they grew."‡

* Mr. Hawkshaw, as Dr. Buckland observes (Address delivered at the Anniversary of the Geological Society, February, 1841), has pointed out that near the shores of the Caribbean Sea the decomposition of the trunks of many trees is so rapid that a few months suffice to leave little else than the bark standing by itself. We have observed facts of a similar kind in Jamaica. Portions of other plants are not unfrequently discovered inside the upright stems in the coal measures, drifted into the hollows of such stems as the accumulations rose sufficiently high to fall into the cavities.

† To remove these stems from the chance of injury, and they might have been readily carried off for building purposes, they were taken up, and placed in the museum of the Royal Institution of South Wales, at Swansea, where they now are.

‡ Anniversary Address, &c., 1841.

Standing, in coal pits or levels, beneath such roofs we have a beautiful exhibition of this growth, supposing it be such, and of the drift above. Here and there a long stem of Sigillaria stretches away for many feet, often as if a fallen plant, and fern leaves, and the stems of Lepidodendron are scattered in all directions. Amid these prostrate plants round circles are to be seen variously distributed, the bases at it were of the stems of Sigillariæ, in the positions where they grew. Allowing for differences of form, the appearance is much that which we should expect if we could view from beneath the clays containing the roots and stems of various trees, mingled with different other plants, and often extensive, known as submarine forests. There would be stems partly erect and partly prostrate, with other plants intermixed in clay in a horizontal position, without order or regularity. When we observe such groups of stems, in the positions in which they grew, as occur at Cwm Llech, we have evidence of a time, during the general subsidence, and subsequent to the conditions for the growth of the plants, constituting the coal, when if there was not exactly dry land, there might have been a marsh or ground liable to be flooded; that it was at least flat and low seems probable.

The solid sheets of argillaceous or clay ironstone, sometimes, though thin (two to five or six inches deep), covering considerable areas, at others represented by nodules abundantly spread over plane surfaces of equal dimensions, are not only objects of great mining importance but also of considerable geological interest. In many bogs of the present day sheets of iron ore, commonly known as *bog iron ore*, are found, but these, though of somewhat variable composition, are usually composed of peroxide with some phosphate of iron. The clay or argillaceous ironstones of the coal measures are not of the same composition, but formed of carbonate of iron, mingled mechanically with earthy matter, commonly corresponding with that constituting the shales with which they are associated. In many of the underbeds or underclays of the coal the same argillaceous iron ore occurs in nodules, irregularly distributed, and is commonly rich in iron in such situations.

Mr. Hunt* having instituted a series of experiments to illustrate the production of these clay or argillaceous ironstones, found that decomposing vegetable matter prevented the further oxidation of the proto-salts of iron, and converted the peroxide into the protoxide of iron, by taking a portion of its oxygen to form carbonic acid. Under the conditions necessary for the production of the coal distributed among the associated sand, silt, and mud, the decomposition of the vegetable matter would necessarily form carbonic acid among other products. This carbonic acid mixed with the water would spread with it over areas of different

* Keeper of Mining Records in the Museum of Economic Geology.

dimensions according to circumstances, forming salts and meeting with the protoxide of iron in solution, it would unite with the protoxide and form a carbonate of iron. The carbonate of iron in solution would mingle with any fine detritus which might be held in mechanical suspension in the same water, and hence when the conditions for its deposit arose, which would happen when the needful excess of carbonic acid was removed, the carbonate of iron would be thrown down mingled with the mud. Under such conditions it would resemble carbonate of lime mingled with mud, and both would alike form impure beds either of carbonate of iron or of lime, as the case may be, according as the matter deposited from solution exceeded that thrown down from mechanical suspension. Both would also form nodules, in the usual manner, occurring in planes amid the mud, where the carbonates were insufficient to constitute continuous beds.

It will readily be understood that according to the variation of conditions would be that of the mechanical and chemical mixture of the carbonate of iron and mud, so that the resulting argillaceous iron ores would differ considerably as to the proportions of the metal contained in them, in the same way as we observe the argillaceous limestones to differ from a similar cause. Argillaceous ironstones might thus be expected to occur in the shales in the same manner as is so commonly seen to be the case with argillaceous limestones and nodules of various geological ages. In the case of coal measures we necessarily infer the supply of the iron instead of the lime. The following analyses of some of the argillaceous ironstones of South Wales, performed at the Museum of Economic Geology, will illustrate the variable amount of earthy matter mechanically mixed with the carbonate of iron.

	Carbonate of Iron.	Earthy Matter.	Metallic Iron.
Upper Vein, Ystradgunlas . .	86·0	14·0	41·5
Another bed, Ystradgunlas . .	72·4	27·6	34·9
Cwm Phil, Ystradgunlas . . .	75·4	24·6	36·4
Pendaren Red Vein	75·4	24·6	36·4
Nodules, Aberpergwm . . .	60·9	39·1	29·4
Pendaren Jack Vein	55·5	44·5	26·6

Carbonaceous matter has lately been found to be mingled with some of the South Welsh argillaceous ironstones, as in the bed known as the *Black Band*, in Scotland. In such cases the carbonaceous matter has been mixed mechanically with the carbonate of iron and earthy substances.* The following are analyses of some of the carbonaceous ironstones, also made at the Museum of Economic Geology:—

* Mr. Hunt, in his experiments, found that pounded coal placed between a galvanic pair, excited by a solution of sulphate of iron, protected this proto-salt from the peroxidation it would otherwise have undergone from the action of the atmosphere.

	Carbonate of Iron.	Carbonaceous Matter.	Earthy Matter.	Metallic Iron.
Cwm Avon bed . . .	51·04	22·16	26·80	24·6
Maesteg Valley beds:—				
No. 1.—Upper band, upper division	63·9	10·0	26·1	30·7
No. 2.—Upper band, lower division	79·9	6·6	13·5	38·5
No. 3.—Lower black band .	76·4	11·0	12·6	36·8
Black Band, 4 inches thick, at Beaufort Iron Works, Pontypool	79·5	16·4	4·1	38·4

The nodules of argillaceous ironstone are very frequently split up internally, the fragments joined by various substances, occasionally leaving empty spaces, like the septaria found in many clay deposits, as, for instance, that of the London clay. There has been an apparent shrinking of the matter of the nodule, the centre splitting to accommodate itself to the exterior form. In the cracks so produced various mineral substances are found, sometimes in a crystallized state, such as pure carbonate of iron, sulphuret of lead, sulphuret of zinc, and sulphuret of copper, which seem to have entered the cavities in the same manner that they might enter the cracks forming the walls of mineral veins. Among the substances so discovered we have obtained the oxide of titanium, which may account for the metallic titanium so frequently found in blast furnaces where argillaceous ironstones have been smelted.

To account for the sulphuret of iron so common in many coal beds, and which must have formed an original portion of them, since it ranges in planes parallel with the coal beds, at variable heights in them, the sulphuret being frequently mingled in part with the coaly matter, and in part occurring pure by itself,† we have to consider that, in waters holding sulphates in solution, the reaction of carbonaceous matter produces a sulphuret of the base. This salt coming into contact with the proto-salts of iron, especially in its nascent state, would form sulphuret of iron. Bischof relates that, having put a teaspoonful of sugar into water containing sulphate of soda in solution, the whole in a pitcher, and having allowed it to remain four years in a cellar, such a quantity of sulphuretted hydrogen was generated as to produce a strong sulphurous

* The following is an analysis of the black band of Lanarkshire, made in the laboratory of the Museum of Economic Geology:—

Carbonate of iron . . .	70·0 = 33·7 metallic iron.
Carbonaceous matter . . .	23·0
Silica, alumina, and a trace of lime .	7·0

† The beds of coal thus containing iron pyrites in bands are usually termed "*Brass Veins*" by the miners, from the colour of the sulphuret of iron somewhat resembling brass.

water. The sulphate of soda formerly in it had disappeared, and iron pyrites was deposited, there having been iron in solution. He also mentions that at the bottom of a spring, containing only a small portion of sulphate of soda, he once found iron pyrites enveloping organic remains, such as the branches and stalks of plants, sulphuret of iron having been formed by the decomposition of the sulphate of soda and the carbonate of the protoxide of iron, at the expense of the organic matter.*

Under this hypothesis we have to consider, in those beds where the bands of iron pyrites noticed are observable, that the iron was introduced in solution, and met with sulphates, also in solution, during the accumulation of the substance of coal, the reaction of the carbonaceous matter causing the production of the iron pyrites, over which the vegetation producing coal was again accumulated, so that the band of sulphuret of iron became interstratified with coal. Respecting the sulphuret of iron introduced into the chinks and partings of the coal, so well known, we have to regard its presence in such situations as so far secondary that the partings and chinks must have been formed after the consolidation of coal itself; so that, if we adopt the explanation above mentioned, we have to suppose a mixture of some soluble sulphate with a solution of the proto-salts of iron, and the introduction of the resulting sulphuret of iron into these partings of the coal, the coal itself performing its part in aiding the necessary decomposition and recomposition. This would appear to give us two epochs for the formation of the iron pyrites connected with coal—one during the accumulation of the vegetable matter in some beds, the other after the beds had been consolidated and the coal separated into the forms often viewed as an arrangement of parts in a manner allied to crystallization.

On the subject of the primary formation, so to term it, of the iron pyrites in the coal, Mr. Hunt has suggested that water, containing oxide of iron, slowly flowing over decaying vegetable matter would pass off, holding carbonate of iron in solution (the needful carbonic acid for such solution being supplied by the decaying vegetation), to be deposited, as previously noticed, with the mud of the time, forming argillaceous ironstones. Should, however, the accumulated mass of vegetable matter be so matted and entangled that the water became stagnant, then, supposing soluble sulphates present, and they are very commonly disseminated in waters, soluble sulphurets would be abundantly produced; they would react upon any carbonate of iron formed in the water, and sulphuret of iron would be thrown down to mingle or be interstratified with the vegetable matter beneath.†

* Reasons against the Chemical Theory of Volcanos, Edinburgh New Philosophical Journal, vol. xxx. p. 23, January, 1840.

† Hunt, MSS.

Though sands were at times distributed among the mud accumulations of the lower shales, so as to form sand beds interstratified with the others, such beds do not often differ, in their present consolidated state, from the sandstones of the coal measures generally, not resembling, by their great hardness, those sand beds of the Farewell Rock or Millstone Grit series which have become quartz rock. In the curvature and denudation of beds which brings up to the surface a portion of the lower shales, with their accompanying relative abundance of coal and ironstone at Maesteg, and thence to Cwn Afon on the west, a sand bed, or rather two or three courses of beds, have become by their mode of consolidation a variety of quartz rock, known as the *Cockshoot Rock**—a rock of much importance to the miner in that part of the country, as showing him his position relatively to certain productive beds of coal. The following section of part of the Maesteg beds will exhibit the position of this Cockshoot Rock:—

Section of the Maesteg Coal Measures from the Cae Defid Vein to the Furnace Vein.

	Ft.	In.
1. COAL (Cae Defid Vein)	5	6
*2. *Underclay*, with nodules of ironstone	3	3
*3. Seam of ironstone	0	3
*4. Shale, with ironstone	6	0
*5. Seam of ironstone	0	5
6. Shale	16	0
*7. Shale, with ironstone nodules	14	0
8. Carbonaceous shale	2	0
9. COAL	0	3
10. *Underclay* (fireclay)	8	0
11. Shale	10	0
12. Sandstone	3	0
13. Shale	4	0
14. COAL (said to be three feet thick, crop only)	0	
15. *Underclay* and black shale	1	6
16. Sandstone	3	0
17. Shale	5	0
18. Sandstone	1	0
19. Shale	10	0
*20. Seam of ironstone	0	3
21. Shale	11	0
*22. Shale, with three seams of ironstone	6	0
23. *Cockshoot Rock* (variety of Quartz Rock)	18	0
24. Shale	12	0
25. Sandstone	0	6

* The term *Cockshut* or *Cockshoot* appears to be derived from the plan formerly adopted in many parts of the country to catch or shoot woodcocks. Long avenues were formed in the woods frequented by these birds in the proper seasons, with nets run up and down vertical posts at the entrance of the avenues, against which the woodcocks flew and were caught. Several places still retain the name of Cockshoot.

		Ft.	In.
26.	Shale	10	0
*27.	Line of ironstone nodules	0	3
28.	Shale	11	6
*29.	Line of ironstone nodules	0	4
30.	Shale	10	6
31.	*Cockshoot Rock* (variety of Quartz Rock)	15	0
*32.	Shale, with ironstone nodules	4	0
33.	Coal	0	9
*34.	*Underclay* and argillaceous shale, with ironstone nodules	6	0
35.	Sandstone	6	0
*36.	Shale, with ironstone nodules	9	0
*37.	Line of ironstone nodules	0	2
38.	Shale	5	6
*39.	Line of ironstone nodules	0	2
40.	Shale	6	0
*41.	Seam of ironstone	0	2
*42.	Shale, with two seams of ironstone	6	0
43.	Coal	2	0
44.	*Underclay*	1	0
45.	Sandstone	0	3
46.	Shale	1	3
47.	Sandstone	0	3
48.	Shale	9	0
*49.	Line of ironstone nodules	0	3
50.	Shale	3	6
*51.	Seam of ironstone	0	3
52.	Shale	1	6
*53.	Seam of ironstone	0	1
54.	Shale	10	0
*55.	Line of ironstone nodules	0	5
56.	Shale	0	8
57.	Coal	1	8
58.	*Underclay* (fireclay)	3	0
59.	Sandstone	0	9
60.	Shale	6	0
61.	Coal	0	9
62.	Carbonaceous shale	1	0
63.	*Underclay* (fireclay)	3	0
64.	Shale	5	6
65.	Sandstone	14	0
*66.	Seam of ironstone	0	8
*67.	Shale, with three seams of ironstone	7	0
*68.	Seam of ironstone	0	6
69.	Shale	9	0
*70.	Line of ironstone nodules	0	5
71.	Shale	3	0
*72.	Seam of ironstone	0	1
73.	Shale	2	0
*74.	Seam of ironstone	0	1
75.	Shale	3	2
*76.	Seam of ironstone	0	3
77.	Shale	0	10
*78.	Seam of ironstone	0	1½
79.	Shale	4	0
*80.	Line of ironstone nodules	0	6

		Ft.	In.
81.	Shale	3	9
82.	COAL	6	0
83.	*Underclay* (fireclay)	2	4
84.	COAL	2	0
85.	*Underclay* (fireclay)	2	0
86.	Sandstone	24	0
87.	Shale	2	0
*88.	Seam of ironstone	0	1½
89.	Shale	4	0
*90.	Seam of ironstone	0	6
91.	Shale	4	0
*92.	Seam of ironstone	0	1
93.	Shale	2	0
94.	COAL	3	0
95.	Carbonaceous shale	6	0
96.	COAL	6	0
97.	Hard and arenaceous rock (*underclay?*)	4	0
98.	COAL	0	4
99.	*Underclay*	4	0
100.	Shale	13	0
*101.	Seam of ironstone	0	3
102.	Shale	3	0
*103.	Seam of ironstone	0	3
104.	Shale	4	6
105.	COAL	0	9
106.	*Underclay* and carbonaceous shale	1	6
107.	Sandstone	5	0
*108.	Line of ironstone nodules, with merely sufficient shale to contain them	0	4
109.	Sandstone	9	0
110.	Shale	2	0
*111.	Seam of ironstone	0	1½
112.	Shale	3	0
*113.	Seam of ironstone	0	4
114.	Shale	3	0
115.	Sandstone	1	6
*116.	Shale, with a course of ironstone nodules	4	6
117.	Sandstone	4	0
*118.	Shale, with ironstone nodules	6	0
119.	Sandstone	6	0
*120.	Line of ironstone nodules	0	2½
121.	Shale	4	0
*122.	Seam of ironstone	0	3
123.	Shale	2	0
*124.	Line of ironstone nodules	0	2
125.	Shale	1	6
*126.	Line of ironstone nodules	0	2
127.	Shale	4	0
*128.	Seam of ironstone	0	3
129.	Shale	3	0
*130.	Carbonaceous shale, with nodules of ironstone	3	0
131.	COAL (Furnace Vein)	12	0
132.	*Underclay*		

The Cockshoot Rock is seen in other localities, and is probably the

sandstone, so named, near Britton Ferry, on the south crop of the coal measures. From the Cockshoot Rock of Maesteg and its vicinity being so quartzose, whenever a bed of somewhat similar lithological character has presented itself, of which there are several local examples, such bed has too frequently been referred to the same geological position as the original rock, thus named, and in consequence several fruitless trials have been made for the coal and ironstone with which it is accompanied at Maesteg. These local lithological conditions of sandstone beds are well known to geologists, and appear frequently due to the very clean quartzose character of portions of the original sand deposit, and to the purity of the siliceous matter which has consolidated them, so that in the continuation of the same beds one portion will be very hard, resembling quartz rock, which it then may be lithologically termed, while others are of a more variable composition and less consolidated.

Above the lower shales, with their relative abundance of coal and ironstone, there is a considerable accumulation of sandstones, the equivalents of which in the Bristol district are known as the Pennant Grit.* In the vicinity of Swansea these rocks form a marked range of country, as also in many other districts. From their superior hardness they commonly constitute escarpments above the lower shales in the Caermarthenshire, Brecknockshire, Glamorganshire, and Monmouthshire coal districts, having better resisted denudation than the softer ground beneath.

Viewed as a whole, coal beds are scarce in this division of the coal measures in South Wales and Monmouthshire, but when they do occur, they are as usual accompanied by their Stigmaria underbeds. Examining as to the probable manner in which the sands composing these sandstones have been accumulated, we find, though there are many cases of solid sandstones, several feet thick, that false bedding, as it is termed, is so abundant, that we may consider the principal mass of sand as having been forced along the bottom by the pressure and movement of superincumbent water, but little having been thrown down in plane horizontal surfaces from mechanical suspension in the water. This kind of accumulation may be readily imitated by experiments, and may also be observed in many a ditch by the road side where arenaceous matter is washed off the road, after heavy rains. It is a kind of deposit, which if the sand be readily supplied, may be effected in very shallow waters, and hence by continued subsidence a very great thickness might be eventually obtained, as is required for this division of the coal measures of the district.†

* It is a rock much employed for building and other economic purposes, not only near Bristol, but very generally where found. Some of the beds supply excellent blocks of a good material for engineering purposes.

† For notice of this kind of accumulation in modern times, see p. 9.

Neither marine nor fresh-water animal remains have hitherto been detected amid this arenaceous deposit on the south-west, and except in the argillaceous shales, sparingly intermingled with it, and chiefly where coal beds are interstratified, finely preserved vegetable remains are also scarce. Multitudes of the stems of Sigillariæ and Lepidodendra, principally of the former, crossed in all directions and matted with each other, as in the annexed sketch* (Fig. 18), are occasionally drifted together

Fig. 18.

in seams, strongly reminding those who have observed the matted condition of torn-up and drifted river-side plants after a flood in the tropics, of similar vegetable deposits. The bark or outside portions of these Sigillariæ and other plants are commonly converted into coal, so that when very thickly accumulated, a seam of coal is produced, rarely however in such a manner that its origin is not apparent.

A much more deceptive appearance, and which when not carefully examined has been taken for a true seam of coal, arises when detrital coal, the remains of pre-existing coal beds, is so accumulated as to form a black seam, the grains and pebbles of coal closely joined together, without other detritus. Coal pebbles were first pointed out to us by Mr. Logan, in 1837, as abundant in the sandstone of the Town Hill behind Swansea, and we subsequently found them more or less common in the same range of sandstones over the South Welsh and Monmouthshire coal field, though by no means confined to them, or beginning with them, for grains of detrital coal have been also observed, though sparingly dispersed, in the sandstones of the lower shales. It was from a rounded pebble of cannel coal, six inches long, four inches wide, and two inches thick, found in an indurated clay, two inches deep, at the top of a bed

* By Miss Woods, in 1838, of a mass from this sandstone near Pembray.

of common bituminous coal, at Penclawdd, on the Bury River, that Mr. Logan directed his attention to this subject. In 1840 he gave an account of the coal conglomerates, of the Town Hill, and Cilfay Hill, Swansea, pointing out that "the coal pebbles are sometimes four inches in diameter, and are confusedly mingled with sand and pebbles of ironstone, and associated with them have likewise been found small boulders of granite and mica slate." So acute and careful an observer was not likely to overlook the mixture of comparatively new and old coal where the drifted Sigillariæ are mixed with the coal pebbles, as is not unfrequent. "Many casts of Sigillariæ and of other plants," Mr. Logan remarks, "coated with coal, occur in the mass; and the difference of age of this coal and that of the pebbles is beautifully illustrated in numerous cases, where the plants have been pressed down on a layer of coal pebbles, which, from their superior hardness, have penetrated into the plants, and thus the newer and the older coal have been brought into juxtaposition; but the crystallization of the former, however distorted the plant may have been, presents an uniform parellelism in the faces of its cleavage, while the cleavage of the older coal is parallel with the sides of the pebbles, which lie in all positions, and very often exhibit the form of a rhomboid with its edges and corners rounded by attrition."*

There are beds of coal gravel without any mixture of ironstone pebbles, and beds of the latter without any of the former, though they are occasionally mixed together, and all are often found without drifted stems of Sigillariæ and other plants. Sometimes fine grains of detrital coal are observed in the diagonal drift producing false bedding, but more commonly the coal gravel and sand occurs parallel to the general plane of stratification, particularly when associated with the stems of Sigillariæ and other plants, as if from the small relative specific gravity of the coal and of the drifted plants, they had been more readily carried forward in mechanical suspension than the common detritus.

The partial abrasion of previously existing coal beds, combined with the general larger size of the detritus moved and deposited, would not only point to a lapse of time sufficient for the consolidation of such previously formed coal beds, but also to an increased power of transport. We have not the same amount of accumulations which might be due to the deposit of fine matter from mechanical suspension or chemical solution, shales being comparatively scarce, and the argillaceous ironstones rare, chiefly confined to the underclays of the coal beds. The coal beds themselves become also comparatively scarce, so that the conditions for the general accumulation have been much modified. Supposing that a certain amount of tranquillity, for a time, was essential to the growth of

* Geological Transactions, Second Series, vol. vi. p. 496.

the plants necessary for the future coal beds, the conditons of this kind have been fewer, and we may consider that sudden minor depressions may have been somewhat frequent, causing the sands, which were pushed along the bottom, to be thrown into a diagonal arrangement as they descended into them. There would not appear to have been the same amount of continued tranquillity as during the accumulation of the lower shales, and the carbonate of iron was not so disseminated amid the deposits as previously.

A good section of these beds, considered the equivalent of the Pennant grit, of the Bristol series, is to be obtained on each side of the Tawe, near Swansea. Both at the Town Hill on the west, and at Cilfay Hill on the east, this part of the South Welsh coal measures is well exposed, and is seen to be formed of a considerable mass of sandstone, as the following section will show.

Section of the Town Hill Sandstones, Swansea.

				Ft.	In.
1. Coal (Hughes' Vein)				5	6
2. *Underclay*				3	0
3. Argillaceous shale				10	0
4. Sandstone				67	0
5. Argillaceous shale				2	0
6. Sandstone, often false-bedded				500	0
7. Coal				2	0
8. *Underclay*				2	0
9. Shale, probably (section not well seen)				140	0
10. Sandstone (irregular bedding frequent)				173	0
11. Coal				1	0
12. *Underclay*				2	6
13. Shale (probably)				90	0
14. Sandstone, with some coal conglomerate, ironstone conglomerate somewhat abundant, false bedding frequent				235	0
15. Fine-grained sandstone, micaceous and gray				65	0
16. Argillaceous shale				120	0
17. Coal	5 ft.	0 in.			
18. *Underclay*	5	0			
19. Argillaceous shale	20	0			
20. Coal	1	2			
21. *Underclay*	2	0			
22. Shale	18	0	(Difatty Veins)	77	0
23. Coal	1	0			
24. *Underclay*	2	0			
25. Shale	20	0			
26. Coal	0	10			
27. *Underclay*	2	0			
28. Argillaceous and arenaceous shale				225	0
29. Arenaceous shale				15	0
30. Sandstone, higher beds slaty, lower beds more thick bedded				107	0
31. Sandstone, beds rather regular, somewhat slaty at top				30	0
32. Sandstone, with coal and ironstone conglomerates and pebbles of granitic rocks (rare). Beds somewhat irregular, with a quantity of disseminated detrital coal				60	0

	Ft.	In.
33. Coal	4	6
34. *Underclay* (fireclay)	2	6
35. Arenaceous shale	40	0
36. Sandstone, irregularly bedded occasionally	283	0
37. Coal	5	0
38. *Underclay*	3	0
39. Arenaceous shale	125	0
40. Coal	3	0
41. *Underclay*	4	0
42. Argillaceous and arenaceous shale	52	0
43. Coal	0	6
44. *Underclay*	1	6
45. Arenaceous shale	23	0
46. Coal	0	6
47. *Underclay*	1	6
48. Sandstone, generally flaggy	150	0
49. Coal (with clay interposed)	9	0
50. *Underclay*	5	0
51. Arenaceous shale	17	0
52. Sandstone, thickly schistose	225	0
53. Coal (Quar Vein)	1	0
54. *Underclay*	3	0
55. Sandstone, commonly flaggy	90	0
56. Coal (Brass Vein)	1	0
57. *Underclay*	2	6
58. Argillaceous shale	110	0
59. Coal	1	6
60. *Underclay*	2	0
61. Argillaceous shale	8	0
62. Sandstone, varying from thick-bedded to flaggy	140	0

This section would give a total thickness of 3,246 feet, showing ten chief masses of sandstone of the respective depths of 67, 500, 173, 300, 197, 283, 150, 225, 90, and 140 feet, together constituting a thickness of 2,125 feet, separated by shales and some coal beds. Even some of the shales are sandy, so that the prevalent character of the general mass is arenaceous; one presenting a marked contrast with that of the great shale, coal and ironstone series beneath.

As might be anticipated from the relative hardness of this sandstone series and of the lower shales, general denudation has so acted that the former may be easily traced from Swansea (and its extension westward to the Bury River) along the southern crop of the South Wales and Monmouthshire coal measures, by Margam, Mynydd Bayden, Mynydd y Gaer, near Llandyfodwg, Llantrissant, the Garth, Caerphilly, and Mynydd Maen to the Pont y pool district. Thence it bends round in an equally marked manner by the northern outcrop of the beds, forming the higher grounds above the ironstone and shale series, to Merthyr Tydfil and Aberdare. A strong escarpment accompanies its range thence to Myndd Rhesolfen, rising above Cwm Neath, on the south

of Aberpergwm. From the Neath valley to Cwm Tawe it likewise rises into high ground, and can readily be followed thence, notwithstanding the contorted country near Llandibie, to the range of Mynydd Pembre, at the western end of which it plunges beneath the flats and blown sands which there border Caermarthen Bay.

Though during the whole of this range the mass of beds may be easily observed, there would appear much local variation, and the streaks of coal beds in it would seem by no means constant to very large areas, with the exception of those in the lower part of the series, which, under various names, appear to have been somewhat widely spread. Though there is no great difficulty in defining the base of this series, in a general manner, the upper boundaries are not so easily fixed when we regard the whole of the South Wales and Monmouthshire coal field. Taking the Swansea section for illustration, we find this series surmounted by the following beds, in the descending order.

Section of the Coal Measures, from the Penllergare Beds to Hughes Seam, near Swansea.

	Ft.	In.
1. Sandstone	25	0
2. Coal	1	3
3. *Underclay*	2	0
4. Arenaceous shale	26	0
5. Coal	1	3
6. *Underclay*	2	0
7. Arenaceous shale, with some sandstone	57	0
8. Coal	2	6
9. *Underclay*	2	0
10. Arenaceous shale	7	0
11. Sandstone	130	0
12. Coal	2	6
13. *Underclay*	1	6
14. Shale	7	0
15. Arenaceous shale, with bands of sandstone	124	0
16. Coal	1	0
17. *Underclay*	2	0
18. Arenaceous shale	57	0
19. Coal	0	10
20. *Underclay*	2	6
21. Arenaceous shale	36	0
22. Sandstone	20	0
23. Arenaceous shale	35	0
24. Sandstone	30	0
25. Argillaceous shale	8	0
26. Coal	3	6
27. *Underclay*	4	0
28. Arenaceous and argillaceous shale	245	0
29. Coal, three seams, shale between	3	0
30. *Underclay*	4	6
31. Argillaceous shale	16	0
32. Hard sandstone	1	0

	Ft.	In.
33. Shale	2	0
34. Sandstone, commonly very hard	9	0
35. Arenaceous shale	8	0
36. Sandstone, very hard	10	0
37. Argillaceous shale	19	0
38. COAL (Church Vein) { Coal 2 ft. 0 in. / Shale 1 0 / Coal 2 0 }	5	0
39. *Underclay*	10	0
40. Argillaceous shale	1	0
41. COAL	2	0
42. *Underclay*	5	0
43. Sandstone	305	0
44. Arenaceous shale, nearly sandstone	37	0
45. Shale	1	0
46. COAL (Five Feet Vein) divided, with shale between the divisions	7	0
47. *Underclay*	7	0
48. Argillaceous shale	51	0
49. Argillaceous shale, alternating with sandstone	48	0
50. Argillaceous shale	106	0
51. Sandstone	29	0
52. Argillaceous shale	70	0
53. COAL	1	0
54. *Underclay*	8	6
55. Shale	108	0
56. Carbonaceous shale	5	0
57. COAL (Six Feet Vein), hard matter in the middle	7	0
58. *Underclay*	6	0
59. Sandstone	2	0
60. Hard arenaceous shale	34	0
61. Argillaceous shale	11	0
62. COAL (Three Feet Vein)	3	0
63. *Underclay*	3	0
64. Sandstone	1	6
65. Arenaceous shale	4	0
66. Slaty sandstone	4	0
67. *Fireclay*	8	0
68. Sandstone	4	0
69. Argillaceous shale	25	0
70. Sandstone	1	0
71. Argillaceous shale	42	0
72. Sandstone	4	0
73. Argillaceous shale	20	0
74. COAL	2	0
75. *Underclay*	3	0
76. Argillaceous shale	24	0
77. Arenaceous shale and sandstone	76	0
78. COAL	1	8
79. *Underclay*	2	0
80. Sandstone	103	0
81. COAL	0	9
82. *Underclay*	1	6
83. Arenaceous shale	34	0
84. COAL	1	3
85. *Underclay*	2	0

	Ft.	In.
86. Arenaceous shale	6	0
87. Sandstone	72	0
88. Arenaceous shale	32	0
89. Coal	1	1
90. Shale	1	0
91. Coal	2	0
92. *Underclay*	2	6
93. Arenaceous shale	25	0
94. Coal	1	7
95. *Underclay*	2	0
96. Arenaceous shale	40	0
97. Coal	1	8
98. *Underclay*	2	0
99. Shale	5	0
100. Coal	0	9
101. *Underclay*	2	0
102. Sandstone	2	0
103. Arenaceous shale	40	0
104. Coal	1	0
105. Shale	1	6
106. Coal	2	0
107. *Underclay*	3	0
108. Arenaceous shale	32	0
109. Coal (Hughes Vein)	5	6
110. *Underclay*	3	0

This section exhibits a greater number of coal beds interstratified with the coal measures than in the subjacent Pennant grit, at the same time that we observe a larger amount of argillaceous shales. Mud has been more frequently and abundantly accumulated in this upper series, which occupies a depth of nearly 3,000 feet, according to this section, one which may be fairly regarded as representing the general fact, though with respect to the real vertical distance between the coal No. 38, and the coal No. 26, there may be, from the absence of conclusive sections, and the occurrence of faults, some few feet doubtful.

Though the Penllergare are the highest beds in a section taken across the coal measures from Bishopston, near Swansea, on the south, to Llandibie on the north, higher beds occur westward. There is some obscurity about the connexion of the Penllergare beds near Gelli organs and those at Coalbrook, about a mile distant on the west, where we find one coal bed six feet thick, and two others each three feet thick. The Llanelly coals are also higher than the Penllergare beds. According to the view of Mr. Logan,* by taking the Sluice Pill seam of the Penclawdd section to be nearly equivalent to Hughe's Vein of the Swansea section, the Penscallen vein of Lwchor would be about 400 feet higher in the series than the Penllergare coals. Although the Llanelly coal measures may not, from faults and unworked ground, be yet well brought into connexion

* Vertical sections of the Geological Survey of Great Britain, sheet No. 2.

with the Swansea coal measures, we may readily consider them, with Mr. Logan, as the highest part of the series known in the South Welsh coal field.

These upper beds above the Town Hill sandstone of Swansea, which we may regard as representing the upper shale series of the Bristol district, as defined by Dr. Buckland and Mr. Conybeare,* may be traced occupying the central part of a trough extending eastward to Mynydd Drumau, Mynydd March Howell, and other localities in that direction. The great central uprise of beds, which at Maesteg brings in the lower shales, throws the equivalents of the Pennant grit on both sides, north and south, so that minor troughs are again produced between this uprise and the main outcrop of the coal measures on the north and south.

On Cefn Morfydd, near Neath, we have high beds in the series above the Six Feet, and other well-known coal beds worked at Swansea. We may also probably view some of the country on the high land between Mynydd Caerau and Mynydd Rhesolfen, such as Cefn Mawr, as formed of the upper series, above the Swansea Town Hill sandstone, but it would soon seem to be cut off by denudations to the eastward, at least as a mass. On the south the upper series appears to be rolled in at Bettws and Llangeinor, and to be continued thence by the country intervening between Llantrissant and Cefn y gwingel, near Llanwynno, the highest beds appearing at Foel Ddyhewy, about 2½ miles N.E. from Llantrissant, a marked seam bed of coal being there worked.

Proceeding from west to east we obtain a modification of the Swansea section, and it soon becomes difficult to distinguish accurately where we should consider the Town Hill sandstones to terminate upwards. The section from Trecastell, near Llanharry (north of Cowbridge), to Mynydd Dinas, rising on the south of Cwm Rhondda,† would give about 2,700 feet of sandstones, with a few beds of coal, which we might refer to the Swansea sandstones, above which, to the top of the sandstones of Tulca Hill, near Collenna, we have 1,650 feet, in which there are several beds of coal, the lower part of some associated shales containing good ironstones.‡ The beds accompanying the Seven Feet Coal at Foel Ddyhewy, above noticed, appear to be still higher in the series.

The Taffe section would seem to show a thinning out of the Swansea sandstones between the last section and the Garth Hill, above Pentyrch, about 1,650 feet at the latter appearing referable to those sandstones. The Maes Mawr coal may represent the bottom of the upper series. In this case a slight portion only of this upper series is to be found in the

* Geological Transactions, Second Series, vol. i. p. 252.

† Horizontal Sections of the Geological Survey of Great Britain, sheet 10, section 4.

‡ Some hard quartzose rock in this part of the section has led to the erroneous supposition that these ironstone-bearing shales were equivalent to the lower shales near Maesteg.

whole section, from the Garth, on the south, to Merthyr Tydfil on the north. The Maes Mawr beds are continued to the vicinity of Caerphilly; after which they are basined out eastward.

A marked bed of coal, known as the Mynyddisllwyn Vein, from having been worked near that place, may be traced over a considerable part of the Monmouthshire coal measures, forming their higher part. The following is a section, by Mr. David Williams, connecting this bed of coal with the lower shales near Pont y pool.

Section of the Higher Coal Measures near Pont y pool.

	Ft.	In.
1. Sandstone		
2. Argillaceous shale	12	0
3. Coal . 3 ft. 0 in. } (Mynyddisllewyn Vein)		
4. Shale . 4 6 } (Mynyddisllewyn Vein)	10	0
5. Coal . 2 6 } (Mynyddisllewyn Vein)		
6. *Soft Underclay*	16	0
7. Flaggy sandstone	704	0
8. Sandstone, mixed with coal detritus	1	0
9. Sandstone	50	0
10. Coal	0	10
11. *Underclay*	3	0
12. Sandstone	150	0
13. Coal	0	10
14. Shale	1	6
15. Coal	0	10
16. Shale	2	6
17. Coal*	2	6
18. *Underclay*	4	0
19. Sandstone	234	0
20. Coal	1	4
21. *Underclay* (fireclay)	3	0
22. Sandstone	150	0
23. Coal, with shale parting	3	0
24. *Underclay*	4	0
25. Sandstone	120	0
26. Coal, with shale parting	2	3
27. *Underclay* (red)	6	0
28. Shale	36	0
29. Coal	0	8
30. *Underclay* (red)	1	6
31. Sandstone	27	0
32. Conglomerate and sandstone	24	0

From No. 7 to No. 25 inclusive, we have a depth of 1,474 feet referable to the Swansea sandstones, still further diminished in thickness from that observed in the southern part of the Taffe Vale section. How far the Mynyddisllwyn Vein may be really distinct it would be difficult to say. Supposing that the Foel Ddyhewy bed is an outlying continuation of it, as has been thought, and that the latter is really above the Tulca

* Considered to be the Troed y rhiw vein of the Merthyr Tydfil district.

beds, near Collenna, as seems to be the case, the whole of these Tulca beds would have disappeared in the distance.

Taking this view, there would be diminished thickness both of the lower shales and central sandstones towards the east, the higher shales and sandstones keeping to the westward, at least so far as regards Glamorganshire and Caermarthenshire, their chief thickness being about Llanelly. Though many coal and other beds may be traced for considerable distances, there is no present evidence to show that any one bed of coal has been continuous over the whole South Welsh and Monmouthshire coal district, nothing that we might consider as representing a contemporaneous growth covering an area of the dimensions required. If further investigations and more extended workings should show any bed spreading nearly over the whole, we should anticipate that some beds in the lower shales would be found the most widely extended, with some beds at the base of the central or Swansea sandstones. The usual character is that of distribution over minor areas, very variable in extent, and the thickest not always spread over the widest spaces.

As the upper sandstones and shales are absent from the west side of this coal field, we are unable to judge of the amount of general thickness in that direction, supposing the upper sandstones and shales to have there once covered the central sandstones, and to have been removed by denudation. The thickness of the coal measures from the upper part of the carboniferous limestone to the top of the central sandstones near Swansea may be taken, including the Gower sandstones and black shales at about 8,600 feet, the total thickness of the coal measures to the Penllergare beds being about 11,000 feet. Mr. Logan has estimated the general thickness, including the Llanelly above the Penllergare beds, at 12,000. Measuring from the Penllergare beds to the northward, we do not obtain the same thickness as on the south, such measurements giving only 8,000 feet for the total thickness, or a difference of 3,000 feet. If we take away about 1,400 feet for the black Gower shales and accompanying sandstones, but slightly shown on the north crop, 1,600 feet remain for the difference in the beds above them, being a decrease of about 1 in 60. Including the Gower shales the decrease would be about 1 in 31, even in that case not exceeding an angle of 2°.

Quitting the great South-Welsh and Monmouthshire coal district, and proceeding to the patch of coal measures occurring at Dean Forest, and preserved from denudation by having been rolled into a basin-shaped cavity, we find the equivalent of the Farewell Rock sandstones and conglomerates covered by sandstones containing beds of coal, which we may refer to the central sandstone series of the Pont y pool district, the suppression of the lower shales amounting to 417 feet in twenty miles, or only 1 in 253, so that if the beds were reduced to their original level,

there would, to the eye, be no appreciable difference from a perfectly horizontal plane. If we take the sandstones from the Lower Trenchard coal to the Lower Church Delf coal, as representing the central sandstones at Pont y pool, there would be a difference (the former being 1,055 feet thick) of 204 feet between the two sections, or a decrease of 1 in 516 for the distance, so that this also would, to the eye, resemble a level plain.

In the Dean Forest section we have beds above the central sandstone not seen at Pont y pool, but which represent the upper shales of the Bristol coal field on the south, and would appear equivalent in geological position with the various beds above the central sandstones of the Neath, Swansea, and Llanelly districts. The thickness of the upper shales and sandstones of Dean Forest is about 1,255 feet, making with 1,055 feet of the central sandstones, and 455 feet of a sandstone series referable to the Farewell Rock, a total depth of 2,765 feet for the coal measures of Dean Forest, in which we have the lower shales absent, the central sandstones, and upper sandstones and shales diminished in general depth from their equivalents westward, and the Farewell Rock increasing in thickness towards its greater developement in the Bristol series. The following is a general section, by Mr. David Williams, and will show the coal measures as developed in Dean Forest.

Section of the Coal Measures in Dean Forest, Gloucestershire.

	Ft.	In.
1. Sandstone	48	0
2. Red argillo-arenaceous shale, with ironstone	30	0
3. Red argillo-arenaceous shale	51	0
4. Sandstone	3	0
5. Blue and red argillaceous shale	24	0
6. Gray sandstone	2	6
7. Red argillo-arenaceous shale	15	0
8. Sandstone	2	0
9. Argillaceous shale	15	0
10. Hard red arenaceous shale	9	0
11. Soft argillaceous shale	9	0
12. Reddish sandstone	3	0
13. Argillaceous shale	21	0
14. Red and gray sandstone	2	6
15. Argillaceous shale	22	6
16. Gray shale	13	0
17. Coal	0	3
18. *Underclay*	4	0
19. Coal	0	6
20. *Underclay*	4	0
21. Argillaceous and arenaceous shale	135	0
22. Coal	0	6
23. *Underclay*	4	0
24. Argillaceous shale	12	0
25. Coal	0	8

	Ft.	In.
26. *Underclay*	4	0
27. Arenaceous shale and sandstone	4	0
28. Sandstone	2	0
29. Argillaceous shale	3	0
30. Sandstone	5	0
31. Gray argillaceous shale	6	0
32. Red argillaceous shale	1	6
33. Sandstone	4	0
34. Greenish arenaceous shale	9	0
35. Argillaceous shale	30	0
36. Coal	0	8
37. *Underclay*	2	9
38. Shale and sandstone	91	0
39. Coal	1	0
40. *Underclay*	1	6
41. Sandstone and shale	80	0
42. Argillaceous shale	12	0
43. Hard, gray, thick bedded sandstone	40	0
44. Arenaceous shale	90	0
45. Sandstone	12	0
46. Coal (Crow Delf)	0	8
47. *Underclay*	3	0
48. Black argillaceous shale	30	0
49. Sandstone	15	0
50. Coal and shale	1	2
51. *Underclay*	3	0
52. Argillaceous shale	9	0
53. Black carbonaceous shale	30	0
54. Coal (Dog Delf)	1	2
55. *Underclay*	2	9
56. Gray argillaceous shale	44	0
57. Coal (Smith Coal)	2	6
58. *Underclay*	3	0
59. Argillaceous shale	29	0
60. Coal (Little Delf)	1	8
61. *Underclay*	3	4
62. Sandstone	2	0
63. Argillo-arenaceous shale	18	0
64. Sandstone	6	10
65. Argillo-arenaceous shale	6	6
66. Argillaceous shale	12	0
67. Coal (Park End High Delf)	3	7
68. *Underclay*	2	8
69. Argillaceous shale	6	0
70. Gray soft sandstone	10	0
71. Argillaceous shale	3	0
72. Coal	0	6
73. *Underclay*	3	6
74. Sandstone	1	4
75. Argillaceous shale	26	0
76. Coal . . . 1 ft. 0 in. 77. Carbonaceous shale 0 6 78. Coal . . . 1 0 } (Starkey Delf)	2	6
79. *Underclay*	3	0
80. Argillaceous shale	10	0

				Ft.	In.
81.	*Soft underclay*			4	0
82.	Coal (Little Coal)			1	1
83.	*Underclay*			0	7
84.	Coal			0	6
85.	*Underclay*			2	6
86.	Argillaceous shale			4	0
87.	Arenaceous shale			10	0
88.	Argillaceous shale			15	0
89.	Coal (Rocky Delf)			1	9
90.	Coal and carbonaceous shale			0	8
91.	*Underclay*			3	6
92.	Argillaceous shale			10	0
93.	Coal			0	6
94.	*Underclay*			3	0
95.	Argillo-arenaceous shale			32	0
96.	*Underclay*			2	0
97.	Sandstone			0	7
98.	Marl			0	6
99.	Sandstone, with drift coal			18	0
100.	*Underclay*			2	0
101.	Coal	0 ft. 8 in.			
102.	Carbonaceous shale	0 9			
103.	Coal	0 6	(Upper Churchway Delf)	4	2
104.	*Underclay*	1 6			
105.	Coal	0 9			
106.	*Underclay*			1	0
107.	Soft argillaceous shale			4	2
108.	Arenaceous shale			1	4
109.	Argillaceous shale			28	0
110.	Coal	1 ft. 0 in.			
111.	Carbonaceous shale	0 6	(Lower Churchway Delf)	2	0
112.	Coal	0 6			
113.	*Underclay*			3	6
114.	Argillo-arenaceous shale			33	0
115.	Sandstone			12	0
116.	Argillo-arenaceous shale			9	0
117.	Coal (Shafnel Delf)			0	6
118.	*Underclay*			2	0
119.	Sandstone and shale			90	0
120.	Coal (Braisley Delf)			1	9
121.	*Underclay*			2	6
122.	Sandstone			380	0
123.	Argillaceous and arenacous shale			21	0
124.	Sandstone			18	0
125.	Arenaceous shale			9	0
126.	Coal (Nag's head or Weaver's)			2	9
127.	*Underclay*			3	0
128.	Sandstone			150	0
129.	Coal (Whittington Delf)			2	6
130.	*Underclay*			3	0
131.	Sandstone			134	0
132.	Coal (Coleford High Delf)			5	0
133.	*Underclay*			4	0
134.	Sandstone			120	0
135.	Coal (Upper Trenchard)			2	0

		Ft.	In.
136.	*Underclay*	3	0
137.	Sandstone	26	0
138.	Marl	1	0
139.	Sandstone	42	0
140.	Coal (Lower Trenchard)	1	4
141.	*Underclay*	2	0
142.	Hard Sandstone	28	0
143.	Red Marl	1	6
144.	Red Sandstone	30	0
145.	Marl	1	6
146.	Hard gray sandstone	30	0
147.	Soft sandstone	39	0
148.	Sandstone	7	0
149.	Marl	1	6
150.	Sandstone	11	0
151.	Marl	1	4
152.	Gray and white sandstone	54	0
153.	Marl and sandstone	1	6
154.	Sandstone	14	0
155.	Marl	1	6
156.	Sandstone	2	0
157.	Marl	0	6
158.	Light gray sandstone	8	0
159.	Marl	1	4
160.	Sandstone	32	0
	(No. 142 to 160, Farewell Rock Series.)		
161.	Gray and red impure limestone.	8	0
	(Commencement of carboniferous limestone series.)		

About nine miles and a half to the south of Dean Forest a considerable mass of coal measures has been preserved from destruction by the denuding causes which have carried off the connecting portion between it and Dean Forest, leaving at least two outlying patches on the north of Chepstow. Some other minor patches of sandstone near the same place can only doubtfully be referred either to the Farewell Rock or the upper part of the carboniferous series, since they thereabouts graduate into each other. The crumpling of the older rocks has been such that an area of about 188 square miles has been rolled into a wide triangular basin-shaped form between Cromhall Heath near Wickwar on the north, and the Mendip Hills on the south, with an offset, between the supporting carboniferous limestone of Bristol and of the Wrington Hills, to Nailsea. A minor patch has been preserved partly by this movement, and partly by a fault on the north of the carboniferous limestone, extending from Clevedon westward to Leigh Down.

In this mass of coal measures, which undulates in various directions and is much covered, especially towards the south, by more modern accumulations, (through which the pits are often sunk, as at Radstock and other places,) we find the divisions first established by Dr. Buckland and Mr. Conybeare, to which we have endeavoured to refer those

which may be formed in South Wales.* To their valuable labours we must refer for a very detailed account of the various localities where the different divisions may be well seen. It may be sufficient to observe that between the Avon and Cromhall Heath, they all occur and may be readily studied. The following section, by Mr. David Williams, of that part of the district, will exhibit the connexion of the various parts, and afford a general insight into the detail, which, as usual, varies in different localities.

General Section of the Bristol Coal Measures.

	Ft.	In.
1. Sandstone	12	0
2. Argillaceous shale	32	0
3. Sandstone	3	0
4. Shale	2	0
5. Sandstone	7	0
6. Hard shale	30	0
7. Carbonaceous shale	1	5
8. Coal	0	1
9. *Underclay*	2	4
10. Argillaceous shale	9	3
11. Coal	0	3
12. *Underclay* (Lower Earth)	1	6
13. Sandstone	6	2
14. Arenaceous shale	12	6
15. Sandstone	9	0
16. Arenaceous shale	10	4
17. Argillaceous shale	7	0
18. Arenaceous shale	20	0
19. Thin seams of Coal, alternating with carbonaceous shale	4	0
20. Coal	1	8
21. *Underclay*	14	0
22. Sandstone	1	6
23. Arenaceous shale	9	0
24. Sandstone	6	0
25. Red shale	18	0
26. Sandstone	18	0
27. Argillaceous shale	25	0
28. Sandstone and shale	160	0
29. Sandstone	73	0
30. Argillaceous shale	75	0
31. Sandstone	13	0
32. Argillaceous shale	20	0
33. Sandstone	8	0
34. Argillaceous shale	20	0
35. Sandstone	33	0
36. Argillaceous shale	26	0
37. Sandstone	12	0
38. Argillaceous shale	24	0

* Observations on the South-Western Coal Districts of England, Geol. Trans., Second Series, vol. i. p. 252.

	Ft.	In.
39. Sandstone	12	0
40. Argillaceous shale	98	0
41. COAL	1	0
42. *Underclay*	7	0
43. Argillaceous shale	30	0
44. Sandstone	35	0
45. Argillaceous shale	3	0
46. Sandstone	2	0
47. Argillaceous shale	3	0
48. Sandstone	4	0
49. Arenaceous shale	29	0
50. COAL	2	5
51. *Underclay*	4	0
52. Arenaceous shale	40	0
53. Argillaceous shale	26	0
54. COAL	1	4
55. *Underclay*	4	0
56. Argillaceous shale	14	0
57. Arenaceous shale	16	0
58. COAL	2	0
59. *Underclay*	5	0
60. Arenaceous and argillaceous shale	42	0
61. COAL (Holybush)	3	6
62. *Underclay*	5	0
63. Argillaceous shale	45	0
64. COAL (Great Vein)	4	6
65. *Underclay*	6	0
66. Argillaceous shale	14	0
67. Sandstone	6	0
68. Arenaceous shale	3	0
69. Argillaceous shale	10	0
70. Argillo-arenaceous shale	11	0
71. Argillaceous shale	10	0
72. Sandstone	8	0
73. Argillo-arenaceous shale	5	0
74. Argillaceous shale	8	0
75. Argillo-arenaceous shale	5	0
76. Argillaceous shale	12	0
77. Arenaceous shale	1	6
78. Argillaceous shale	20	0
79. Sandstone	8	0
80. Argillaceous shale	7	0
81. Sandstone	1	0
82. Argillaceous shale	20	0
83. Argillo-arenaceous shale	11	0
84. Argillaceous shale	31	0
85. Hard arenaceous shale	8	0
86. Red argillaceous shale	10	0
87. Arenaceous shale	5	0
88. Red argillaceous shale	22	0
89. COAL	1	6
90. *Underclay*	3	0
91. Hard arenaceous shale	10	0
92. Sandstone	74	0
93. Hard argillo-arenaceous shale	11	0

		Ft.	In.
94.	Red and gray argillaceous shale	15	0
95.	Arenaceous shale	8	0
96.	Sandstone	19	0
97.	Sandstone, with drift coal	3	6
98.	Argillaceous shale	58	0
99.	Sandstone	8	0
100.	Argillo-arenaceous shale	6	0
101.	Coal	1	6
102.	*Underclay*	4	0
103.	Argillaceous shale	4	6
104.	Sandstone	4	0
105.	Red argillaceous shale	50	0
106.	Argillo-arenaceous shale	34	0
107.	Sandstone	8	0
108.	Red argillaceous shale	20	0
109.	Sandstone	9	0
110.	Red argillaceous shale	20	0
111.	Hard sandstone (Pennant)	150	0
112.	Hard sandstone, with beds of shale and thin seams of Coal	450	0
113.	Coal	2	0
114.	*Underclay*	4	0
115.	Gray sandstone (Pennant)	422	0
116.	Coal	1	6
117.	*Underclay*	4	0
118.	Sandstone	57	0
119.	Gray sandstone (Pennant)	324	0
120.	Coal (Cock Vein)—parting between two coals	3	0
121.	*Underclay*	3	6
122.	Hard sandstone	92	0
123.	Coal (Chick Vein)—parting between two coals	1	6
124.	*Underclay*	4	0
125.	Sandstone and shale	95	0
126.	Coal (Hen Vein)	2	6
127.	*Underclay*	2	0
128.	Sandstone and shale	102	0
129.	Coal	3	0
130.	*Underclay*	3	6
131.	Shale	9	0
132.	Sandstone and shale	18	0
133.	Coal	2	0
134.	*Underclay*	3	0
135.	Shale	8	0
136.	Sandstone	3	6
137.	Argillaceous shale	37	0
138.	Sandstone	1	0
139.	Argillo-arenaceous shale	19	0
140.	Sandstone	4	0
141.	Argillaceous shale	39	6
142.	Coal, with three partings (Britain's Vein)	4	0
143.	*Underclay*	4	0
144.	Argillaceous shale	87	0
145.	Coal (Stubbs' Vein), four partings	6	0
146.	*Underclay*	3	6
147.	Sandstone	4	0
148.	Argillaceous shale	20	0

	Ft.	In.
149. Arenaceous shale	8	0
150. Sandstone	1	8
151. Red and gray argillaceous shale	17	0
152. Sandstone	5	0
153. Red argillaceous shale	23	0
154. Sandstone	1	0
155. Gray argillaceous shale	5	6
156. Sandstone	2	6
157. Red argillaceous shale	9	0
158. Sandstone	1	0
159. Red argillaceous shale	28	0
160. Sandstone	6	0
161. Argillaceous shale	14	0
162. Coal	1	0
163. *Underclay*	6	0
164. Sandstone	13	0
165. Argillaceous shale	50	0
166. Arenaceous shale	9	0
167. Argillaceous shale	185	0
168. Sandstone	4	0
169. Coal	1	6
170. *Underclay*	2	0
171. Argillaceous shale	64	0
172. Coal and shale	4	0
173. Coal	1	0
174. *Underclay*	4	0
175. Argillaceous shale	4	0
176. Sandstone	2	0
177. Argillaceous shale	23	0
178. Coal	0	9
179. *Underclay*	3	6
180. Coal	0	6
181. *Underclay*	2	0
182. Argillaceous shale	7	0
183. Sandstone	1	0
184. Argillaceous shale	2	0
185. Sandstone	6	0
186. Argillaceous shale	4	0
187. Coal	2	4
188. *Underclay*	2	0
189. Sandstone	3	0
190. Argillaceous shale	4	0
191. Coal (thin seam).		
192. *Underclay*	3	0
193. Argillaceous shale	13	0
194. Arenaceous shale and sandstone	17	0
195. Coal	1	0
196. *Underclay*	3	0
197. Arenaceous shale	6	0
198. Coal (thin seam).		
199. *Underclay*	3	0
200. Argillo-arenaceous shale	5	0
201. Coal (thin seam).		
202. *Underclay*	2	0
203. Argillo-arenaceous shale	40	0

	Ft.	In.
204. COAL (with two partings of shale)	3	0
205. *Underclay*	4	0
206. Arenaceous shale	12	0
207. COAL	1	0
208. *Underclay*	2	6
209. Arenaceous shale	4	0
210. COAL and shale	3	0
211. *Underclay*	4	0
212. Arenaceous shale	2	0
213. Argillaceous shale	8	0
214. Sandstone	4	6
215. Arenaceous shale	5	0
216. Sandstone	10	0
217. Argillaceous shale	2	0
218. COAL and shale	3	0
219. *Underclay*	3	6
220. Argillaceous shale	8	0
221. COAL	1	8
222. *Underclay*	2	6
223. Uncertain ground	148	0
224. COAL	1	0
225. *Underclay*	3	0
226. Argillaceous shale	12	0
227. Sandstone	5	0
228. Argillaceous shale	10	0
229. COAL	2	0
230. *Underclay*	2	6
231. Argillo-arenaceous shale	26	0
232. COAL (thin seam).		
233. *Underclay*	2	0
234. Argillaceous shale	16	0
235. COAL (thin seam).		
236. *Underclay*	5	0
237. Black and gray argillaceous shale	18	0
238. Sandstone	6	0
239. Black and gray argillaceous shale	25	0
240. Arenaceous shale	2	0
241. Hard sandstone	22	0
242. Sandstone, with coal-pebbles and sand	3	0
243. Sandstone	7	0
244. Sandstone, with coal-pebbles and sand	2	0
245. Sandstone	7	0
246. Argillaceous shale	1	6
247. Sandstone	10	0
248. Black argillaceous shale	30	0
249. COAL (thin seam).		
250. *Underclay*	3	0
251. Argillaceous shale	9	0
252. Sandstone	1	6
253. Argillaceous shale	4	0
254. COAL (thin seam).		
255. *Underclay*	2	0
256. Hard white sandstone	23	0
257. Argillaceous shale	5	0
258. Sandstone	3	0

	Ft.	In.
259. Argillaceous shale	3	6
260. Coal (thin seam).		
261. *Underclay*	2	0
262. Argillaceous shale	18	0
263. Coal (thin seam, with parting).		
264. *Underclay*	2	0
265. Arenaceous shale	17	0
266. Coal and shale	5	0
267. *Underclay*	5	0
268. Argillaceous shale	15	0
269. Coal (thin seam).		
270. *Underclay*	4	0
271. Coal	1	0
272. *Underclay*	4	0
273. Coal (thin seam).		
274. *Underclay*	5	0
275. Sandstone	3	0
276. Argillaceous shale	9	6
277. Sandstone	5	6
278. Coal (thin seam).		
279. *Underclay*	2	6
280. Argillaceous shale	3	0
281. Coal.		
282. *Underclay*	3	0
283. Sandstone	3	0
284. Argillaceous shale	8	0
285. Coal.		
286. *Underclay*	3	0
287. Argillaceous shale	2	6
288. Sandstone	1	0
289. Argillaceous shale	3	0
290. Black carbonaceous shale	12	0
291. Coal (eight seams) 292. *Underclay* (eight beds)	24	0
293. Sandstone	12	0
294. Argillaceous shale	5	0
295. Hard sandstone, approximating to quartz rock; sometimes mixed with softer beds; frequently red. Bed of coal about 400 feet from the base (Farewell Rock)	1200	0

We thus have here about 1,000 or 1,200 feet for the Farewell Rock series, 1,565 for the lower shales, 1,725 feet for the central sandstones or Pennant grit, and about 1,800 for the upper sandstones and shales, making a total of 6,280 feet for the thickness of the coal measures in the Bristol district. This is probably the general thickness of the parts and of the whole, in the coal country extending from the Avon to the Mendip Hills. In the general area the undulations have been such that an anticlinal ridge raises up the Farewell rock series from St. George's, near Bristol, to Holy Trinity; that the Nailsea beds are rolled into a minor basin, and that the rocks are highly inclined and contorted where the coal measures rest against the northern flank of the Mendip Hills, from the Stratton coal-works to Vobster.

As the coal fields above noticed have been preserved as we now find them, by the crumpling of the older rocks, and by the subsequent denudations having been such as to prevent their removal with those parts that once joined their now isolated portions together, we should expect that coal measures would be again rolled in on the south of the Mendip Hills, as they are on the north, more particularly as there is no geological reason for concluding that, anterior to the movement which forced the old red sandstone and carboniferous limestone of the Mendip Hills into their present crumpled form, the coal measures terminated where the general horizontal plane now cuts them on the north of these hills. On the contrary, we seem to have the coal measures of Vobster, Radstock, and other places, largely developed, so that there is reason for concluding that they were also rolled over with the higher beds of the carboniferous limestone which we see dipping southerly on the southern flank of the Mendips, continuing with a proper outward dip from Cloford towards Frome, the old red sandstone and carboniferous limestone of Bradford Bridge near Frome (a continuation of the Downhead and Leigh-upon-Mendip anticlinal line), showing the direction in which the older rocks are ranging in that part of their course. In the Mendip Hills, as near Bristol, there is much difficulty in making a real distinction between the upper part of the carboniferous limestone and the lower part of the Farewell Rock series, so that when we see (as was found by Mr. Williams) sandstones like those of the Farewell Rock, about two miles east of Wells, with Calamites and Sigillariæ, and on the west of the same town similar sandstone, with a small seam of coal in it, dipping at a high angle (70°) to the south, we are not sure that we actually arrive at the coal measures, though we perceive that we are in a certain part of the series, marked by similar beds near Bristol.

How far coal measures which could be profitably worked may approach the Mendip Hills on the south and west, we have no knowledge. The patches of carboniferous limestone protruding through more modern deposits, on the south of Chedder, Westbury, Dinder, and Croscombe, are sufficient to show that the older rocks are thrown into many a large ridge and furrow, as they descend beneath the level of the new red sandstone and oolitic series, and to warn those, who might speculate upon finding coal by sinking sufficiently deep, that, instead of reaching coal measures, any such pit might descend upon the back of a subterraneous ridge of carboniferous limestone, or even upon old red sandstone. This will be readily understood, if all the carboniferous limestone and old red sandstone between the South Welsh and Monmouthshire coal district and the Mendip Hills, with the coal measures of Dean Forest, and of the Bristol district, were concealed by a covering of more modern

rocks, and a pit were sunk in any part of the general area upon the chance of cutting into the coal measures, or a profitable part of them.

In like manner though we might suspect that the coal measures, amid their undulations, might bring in other patches of profitable coal beds, beneath the lias and oolite towards Bath, in the same way as the patch is found at Newton, where it becomes exposed from the covering of more modern deposits having been removed by denudation, it might as easily happen that the general crumpling of the older rocks brought up portions of carboniferous limestone. The Week Rocks show that which might readily be expected beneath also in the shape of faults, as well as from the rise of the limestone, since both an uprise of the carboniferous limestone and a great fault, bringing Farewell Rock against the former, are to be there seen.

From the movement of the older rocks many a mass of coal measures may be buried beneath the oolites and cretaceous rocks on the east, the remains of a great sheet of these accumulations, connecting the districts we have noticed with those of Central England and of Belgium, rolled about and partially denuded prior to the deposit of the new red sandstone. We, as it were, just perceive the trace of a mass of coal measures descending beneath the poicilitic and oolitic rocks of the vale of the Severn near Newent. At Bowlsden we find the coal measures resting upon old red sandstone, so that the overlap seen at Howl Hill (p. 202) has continued until it spread beyond the limits of the carboniferous limestone. The coal measures at Bowlsden appear chiefly to be composed of argillaceous shales, and therefore neither agree with the Farewell rock nor with the central sandstones (Pennant Grit), which are so well seen only five miles distant on the south-west, across the high ground of May Hill, the uprise of which we should consider, in accordance with the geological facts observable in the district, to have taken place after the deposit of these Bowlsden beds. The following is a section of the Bowlsden beds, as constructed from the information of an old miner who had worked in the pits :—

	Ft.	In.
1. New Red Sandstone and conglomerate, unconformably covering the coal measures		
2. Shales, with thin seams of coal, and some beds of sandstone . .	120	0
3. Coal	5	6
4. *Underclay*	4	0
5. Similar beds to No. 2	120	0*

The edge of the same range of coal beds can be observed interposed

* The workings were abandoned in consequence of the bad state of the roof above the coal, requiring large quantities of timber for support. A trial pit, sank 600 feet more to the southward, and which should have cut the coal No. 3, went through nothing but shales, with thin seams of coal and beds of sandstones, so that there must be a considerable fault between the Bowlsden pit and this trial pit.

between the old and new red sandstones for two or three miles from Hill House colliery, about two miles west of Newent, and slight workings are still carried on near the latter place. The beds dip beneath their covering of the poicilitic series, and small as the traces of them are, they are sufficient to show us the probability of coal measures extending to the eastward, beneath their covering of more modern rocks, and to aid us in connecting the coal measures of the south-west with the Shropshire and North-Welsh accumulations of the same date.

With respect to the coal measures of Devon and West Somerset, first pointed out to be such by Professor Sedgwick and Mr. Murchison,* and which rest on the black limestones previously noticed (p. 135), the contortions which they have suffered have been so considerable that it is not easy to estimate their thickness. Though so contorted, the sections exposed near Bideford sufficiently show that, above the black limestones and shales of Muddlebridge, the base of this accumulation is chiefly composed of argillaceous slate, in which there are some thin bands of sandstone, and that the latter increase to the southward, so that at Temcot and Lancross they greatly prevail. Sandstones would appear more abundant generally in the higher than in the lower parts of the mass of these accumulations. Anthracite beds, long known and worked, range from the coast, near Bideford, through that town eastward, in the line of strike for about twelve miles and a half, the anthracitic matter disappearing in that direction, so that while three beds occur near Bideford, a single bed only is observed on the eastern end. Argillaceous ironstones are also found in this part of the series, some in Stigmaria beds. Some red beds are also observed among the mass, but generally in situations where we may suppose that, from a covering of new red sandstone, now removed by denudation, the peroxide of iron had found its way downwards into the subjacent coal measures.

Comparing the Devon beds with those at Swansea, we should feel disposed to regard them more as equivalent to the sandstones and shales which cover up the black shale of the Gower section, and support the great mass of lower shales, with their abundance of ironstone and coal, than as representing the lower shales themselves. If they are in any way equivalent to the latter, the conditions for the deposits in Devon must have varied materially from those in South Wales, for while the vegetable matter forming the coal was abundantly accumulating in the latter, in the former it would be scarce. The absence of coal may indeed show that the land, in this part of the general area, was not sufficiently long above water to permit the necessary growth, while towards Wales and the Bristol district the opportunities for such growth

* On the Physical Structure of Devonshire, Geological Transactions, Second Series, vol. v.

were far more frequent. We can readily understand a more rapid descent of the bottom beneath the waters southward than northward, so that not only greater accumulations were effected at equal times in the former, but land also was seldom sufficiently long above water to permit the growth of the plants which should form future coal beds. If such were the case we have no evidence, as yet produced, to show that the coal-measure deposits of Devon were accumulated in a sea more than those of Wales, Monmouthshire, Gloucestershire, and East Somerset, for hitherto the same kind of organic remains have been alone found.

From Bideford to Kittisford there is much sameness in the sections; a sand may have become more mingled with mud in one place than in another, and even be replaced by it, so that sandstones may be observed in the line of strike to graduate into shales, yet as a whole the general character is much the same, so that these upper beds offer little variety.* Here and there false bedding shows that the accumulation of sands has been produced by the action of water shoving the grains along the bottom, and many a surface ridged and furrowed points to minor friction on the bottom. Vegetable impressions, though rare in some parts of the series, are sufficiently abundant in others, the delicate ferns beautifully preserved in the shales, and the coarser plants marking more irregular drift among the sandstones. These plants have been shown by Professor Sedgwick and Mr. Murchison to be the same with those usually found in the coal measures.†

Looking at the accumulations above noticed as extending from Pembrokeshire along South Wales into Monmouthshire, Gloucestershire, Somerset, and Devon, we have a mass of detrital matter of great collective bulk, mingled with the remains of plants, part of which we may regard as having grown where we now find their remains, and part as transported by the waters from greater or less distances. In the fine sediments the most delicate plants are uninjured, in the coarse detritus they are more broken and less well preserved. In all this area, thick as the accumulations are still seen to be in several localities, we have no reason to suppose that any of them were effected in the sea, since no trace of marine remains have, as yet, been detected in them, and should any be hereafter discovered, the case will be an exception to the general evidence. Though we have to reckon the depth by thousands of feet, there is less evidence of the accumulations having been effected in deep than in shallow water, and we require frequent conditions for large surfaces to have been covered by vegetation, parts of the plants, at least,

* As an accidental variety Professor Sedgwick and Mr. Murchison point out calcareous shale, passing into impure limestone, near Hatherleigh. Physical Structure of Devonshire, Geol. Trans., Second Series, vol. v. p. 678.

† Ibid., p. 681.

being in contact with the atmosphere, and we have to look to continued depression as a whole, though such depression may have been unequal at different times, to account for the repeated growths of one sheet of vegetation above another, with interposed detrital accumulations.

The modified composition of the coal in our district, from that kind commonly termed bituminous to anthracite, is a subject of considerable interest. It is well known that in coal districts generally one bed of coal differs from another in its quality, even parts of the same bed being variable in this respect; a bottom or an upper portion, as the case may be, sometimes only separated by a thin parting of shale, being of a different quality from that above or below it. In such cases there have evidently been some modifying conditions sufficient for the difference. In a series of strata one coal bed will be sought for one purpose, another for another purpose, it having been practically ascertained that each was thus applicable. Upon carefully inspecting the coals which so vary in quality, there seems no reason to suppose that the vegetation supplying their substance had differed. The same kind of Stigmaria beds are discovered beneath them, similar kinds of plants in the coal itself, when any form can be traced, and similar plants in the shales or sandstones interstratified with them. The differences seem chiefly due to the conditions which have succeeded to the accumulation of the vegetable matter, though, no doubt, variable proportions of earthy ingredients have often also to be regarded as an original difference.

In our district we have not only this kind of difference, one so common to most coal districts, but also a great marked change of the mass of the coal beds from the, so called, bituminous state to that of anthracite. We see the same series of coal beds becoming so altered in their horizontal range that a set of beds bituminous in one locality is observed gradually to change into anthracitic in another. We find that the matter of the coal bed gradually presents a larger proportion of carbon to the oxygen, hydrogen and nitrogen; so that if we assume the whole to have been once composed of nearly similar relative proportions of these substances, a far greater change has been effected in the original composition in one place than in another.

Taking the coal measures of South Wales and Monmouthshire, we have a series of accumulations in which the coal beds become not only more anthracitic towards the west, but also exhibit this change in a plane which may be considered as dipping to the S. S. E. at a moderate angle, the amount of which is not yet clearly ascertained, so that in the natural sections afforded we have bituminous coals in the high grounds and anthracitic coals beneath. This fact is readily observed either in the Neath or Swansea valleys, where we have bituminous coals on the south and anthracite on the north, and more bituminous coal beds on the

heights than beneath some distance up these valleys, those of the Nedd and Tawe. Though the terms bituminous coal and anthracite have been applied to marked differences, the changes are so gradual that there is no sudden modification to be seen. To some of the intermediate kinds the term "free burning" has indeed been given, so that three chief differences have been recognised.* These, however, so shade away into each other that, following the same beds, it always becomes difficult to assign distinct names to the varieties, though the great change is manifest.

The lower shales, which are so much worked for the coal and iron in them, afford excellent examples of this change of bituminous into anthracitic coal. The series of deposits is easily seen to be the same, and many coal beds can be traced for considerable distances and observed to be altered in their range, as can be well studied between Pont y pool on the east to Merthyr Tydfil on the west. So little bituminous have some coal beds of this series become at the latter place, that they are there employed without coking for the iron furnaces. These same beds, five miles still further west, at Herwaun, have become so anthracitic that they are not employed for the furnaces; we there also see a good example of the anthracite beds dipping beneath those which still continue somewhat bituminous in the heights above, themselves changing in their further range westward. We have, therefore, not only to consider the change as it proceeds from east to west, but also that taking place perpendicularly to the plane before noticed, and to make allowance for the position of the coal beds in the mountains relatively to both. A matter of no small importance when coals fitted for different purposes are sought, for the same beds thus present changes, and may be worked for different uses in their extended course. Hence, viewed as a whole, this coal district is one capable of supplying fuel of great variety, valuable for numerous and different purposes.

Seeking for any original difference in the coal we find nothing leading us to infer that this has been the case, so that we turn to subsequent changes to explain the facts observed. Liebig has pointed out those which woody fibre has probably undergone in the formation of coal. After noticing the alteration produced in woody fibre when the access of air is restrained, and those which have probably caused the conversion of this fibre into lignite, where more hydrogen is discovered than in wood, and less oxygen than is necessary to form water with this hydrogen,

* The term *culm* is applied both to an inferior kind of anthracite, and to the small pieces of good anthracite, or stone coal, obtained in working the good anthracite beds, the larger pieces of the same bed being thus termed anthracite, or stone coal, and the smaller pieces culm. Some beds of inferior anthracite are only worked for making lime or for mixing with clay, and the coal raised is then usually termed culm.

he observes that from the analyses by Richardson and Regnault of splint coal from Newcastle and of cannel coal from Lancashire, it would appear that these coals were formed from the elements of woody fibre by the removal of a certain quantity of carburetted hydrogen and carbonic acid.*

Taking Liebig's view of the decomposition of the vegetable matter which has produced the coal, we find retained in the present composition of the coal only so much of the amount of oxygen, hydrogen, nitrogen, and carbon, contained in the original mass of vegetation, as has not been removed by such decomposition. If, therefore, the gases or volatile compounds formed have removed relatively greater proportions of the hydrogen and oxygen than of the carbon, it follows that the latter finally prevails to a greater extent than it did at first, and might, the same causes continuing, constitute nearly the whole substance of the coal. Consequently when we see such differences as the following exhibited in the coals, extending our view to Dean Forest, we have to consider that the decomposition of the vegetable matter has been more complete in the one than the other.

	Churchway High Delf Forest of Dean.	Bryn Dewy Neath.	Lower Grais Vein, Fforest Works, Llanelly.
Carbon	71·14	79·78	88·06
Hydrogen	4·90	4·98	2·71
Nitrogen	1·41	1·58	1·06
Oxygen and loss	7·65	7·16	4·52
Earthy matter	10·22	5·05	1·20
Moisture	4·68	1·45	2·45†

That changes are now going on by which the proportion of carbon to the oxygen, hydrogen, and nitrogen, is increased, we have abundant evidence in the carbonic acid, carburetted hydrogen, and other products evolved from the coal, and so fearfully known to the coal-miner. And this not only where the coal is wrought, and opportunities thus afforded, not previously presented, for the ready discharge of these gases, but naturally also, the gases rising to the surface through cracks and fissures.

It has been supposed, with reference to a similar change in an old series of coal measures from bituminous to anthracitic coals, in the United States, that the contorted and violently disturbed condition of

* Liebig, Chemistry in its application to Agriculture and Physiology, edited by Dr. Lyon Playfair, second edition, p. 350.

† The composition of the anthracite worked near Bideford, Devon, is as follows:—

Carbon	87·62
Hydrogen	3·34
Nitrogen	1·09
Oxygen and loss	3·24
Earthy matter	3·38
Moisture	1·33

the coal measures in one part of the general area, there occupied by them, and their comparatively undisturbed state in the other, has been favourable to the escape of oxygen and hydrogen, combined with a proportion of the carbon, in the one district greater than in the other, so that the coal became anthracitic in the former case.* This view, however satisfactory it may appear for the variations observable in the great North-American coal district, does not apply to the coal measures of South Wales and South-Western England, which we have to regard as one thing, however it may be now divided up by the movement of the earth, and by denudations. The coal measures at Merthyr Tydfil, where the coal of the lower shales is far less bituminous than at Pont y pool, are not more disturbed than at the latter place. A section from Pyle on the south, to Herwaun on the north, will show the bituminous coal at the former far more disturbed than the anthracite at the latter; and the bituminous coal of Vobster, near the Mendip Hills, is far more contorted than a great proportion of the anthracite of Glamorganshire and Caermarthenshire. We have bituminous coals on the high grounds of part of the South Wales coal district, as above noticed, and anthracite beneath, so that a higher position, or greater facilities of decomposition thence arising, has not been the cause of the change.

To consider this subject properly we should scarcely confine ourselves to the district under consideration, but include the anthracite district of Kilkenny, which seems to have been subjected to the same conditions, appearing to point out that the cause of the change of bituminous coal into anthracite was of an extended kind; and we may observe that the coal measures of Kilkenny, Carlow, and Queen's County, rest, with but slight undulations, on the carboniferous limestone supporting and surrounding them.

We have evidence in the Scotch coal measures that bituminous coal can be changed into anthracite when dykes or masses of igneous rocks have been thrust through them or into fissures among them, the coal being charred near the igneous rocks, and anthracite at a short distance, this character changing by degrees to the unaltered state of the coal bed. Anthracite has also been produced by artificial means, before the introduction of the hot blast into the manufacture of iron, when it was of importance to procure the largest amount of combustible matter without possessing the bituminous qualities of common coal. This Mr. Oakes of the Alfreton Iron Works effected, by exposing coal to a very gradual

* Prof. H. D. Rogers (Transactions of American Geologists, p. 470) shows that in the great Apalachian Coal Field, extending 720 miles, with a chief breadth of 180 miles, the coal is most bituminous towards the western limit, where it is level and unbroken, becoming anthracitic towards the south-east, where it is disturbed. Mr. Lyell treats also of the same subject, Travels in North America, p. 91.

application of heat, thus converting it into a complete anthracite, and not into coke.*

We may, therefore, fairly refer to long-continued high temperature and its consequences as capable of effecting the change of bituminous coal into anthracite, or in other words, as advancing the process by which the oxygen and hydrogen, combined with a certain proportion of the carbon, are driven off, gradually increasing the proportion of the carbon in the solid part left behind. If we could imagine a portion of the coal area to have been depressed during the lapse of geological time, much below the other parts, and thus brought more within the influence of internal heat, so that one part of the mass, and therefore continuous portions of the same series of coal beds, became so situated that the decomposition of the mass of the coal proceeded faster during a given time in that part than in another, we should have an explanation in accordance with the alteration of bituminous coal by the intrusion of igneous rocks, or by artificial means. Be this as it may, the influence of heat is a cause of alteration not to be disregarded, more especially when we find the lower coal beds anthracitic, and the upper beds more bituminous, where the plane of change cuts through the South-Welsh coal measures, pointing to an influence acting from beneath, and not from above.

Undulations and Contortions of the older Rocks. Granites and Elvans. Older Faults.

That there was any material disturbance of the rocks in the southern portion of our district, and indeed so far as surface evidence is afforded, on its eastern part, to the close of such of the coal measure deposits as are known to us, does not appear. From facts observed on the opposite districts of Ireland, the extent to which the older rocks of Wales may previously have suffered from contortion and violent movement remains to be ascertained. Part of Southern Wales seems to have partaken of the pressure which in South-Eastern Ireland is so well seen to have acted violently on the older fossiliferous rocks, anterior to the deposit of the old red sandstone and carboniferous limestone of that country. The overlap of the old red sandstone, carboniferous limestone, and coal measures of Pembrokeshire, may be regarded as a modified prolongation of this movement, the effects of which became lost, as it were, in the direction of Herefordshire and Shropshire. Without the aid of the Irish sections, and these are as clear as could be desired, the value of the overlap in Pembrokeshire, as pointing to any great double and consecutive movements which the older rocks of Wales and Southern England may have experienced would scarcely have appeared. It would be premature,

* Specimens of this artificial anthracite are preserved in the Museum of Economic Geology.

before the survey of the whole of Wales shall have been completed, to examine far into the evidence of any movement corresponding with that observed in South-Eastern Ireland, where we find two movements so well exhibited, one anterior to the deposit of the old red sandstone, the second subsequent to it. Taking the counties of Wicklow, Wexford, and Waterford, we see that the strike of the older line of rolls or upheaval, though often modified, the result of pressure upon the then existing stratified mass, is about N.N.E. and S.S.W.; while the second movement, forcing the old red sandstone and carboniferous limestone into huge ridges and furrows, especially on the south of Ireland (including the older and previously upturned rocks, as well as the covering of these two rocks above them), is marked by east and west lines.

Any good geological map of the British Islands will show that these great east and west lines are continued, though on a minor scale, into Southern Pembrokeshire. In the latter country, a slight trace only is observable of the movement preceding these east and west lines, and which is marked by so much disturbance in Ireland. Slight, however, as it may be, it is yet sufficient to induce us to suspect that the date of many lines of disturbed older rocks in many parts of more Northern Wales may have been included in the movements which first affected the older fossiliferous rocks of Ireland opposite.

Such movements of the older rocks are most valuable when we reason on the great physical changes which have taken place, and have been accompanied by detrital or calcareous deposits, marked by many important modifications, both lithological and palæontological. It is evident that the appearance of dry land above the sea, and the condition of the sea bottoms themselves, must have been much modified by them. The evidence of lateral pressure in these older movements is very considerable, so that if the multitude of contortions, domes, cavities, and flexures, into which the beds have been forced were flattened out, the area covered would be far more extensive than that now occupied by the same beds in their squeezed and crumpled state. How far there has always been displacement caused by the intrusion of igneous rocks, and producing this lateral pressure, such igneous rocks, in a great measure concealed from surface exposure by more modern accumulations of various kinds, is matter of research; but whether this explanation, or that supposing an adjustment of the surface of the globe at various times and places to a diminished volume of the earth from cooling, be the true one, lateral pressure seems evident from the singular folding and contortion of the beds, so frequently and so easily seen in many districts.

The northern and southern strike of the beds between Aberystwith and Cardigan sweeps round near the latter place in a curve to an east and west direction, in the vicinity of Fishguard, where the beds are much

twisted, horizontally as well as vertically. This east and west range of contortions may have been the result of pressure, subsequent to the more northern and southern arrangement of great ridges and furrows, as has happened in the opposite land in Ireland; and we may, therefore, in the northern part of Pembrokeshire, have the complicated forms resulting from a twist of rocks in a new direction over an older one.

In Southern Pembrokeshire lateral pressure has forced the rocks into east and west directions; some parts, either from unequal application of the force, at different points, or from unequal resistances, having been squeezed up higher in some places than in others, forming local oval protrusions. This east and west range of country may be viewed as continued towards Cardiff and Newport, beyond which a bend to the northward takes place, and in it is thrust up the Silurian rocks of Uske.

As the result of this movement, the coal measures of South Wales and Monmouthshire have been forced into a basin-formed cavity, with minor undulations, the chief of which, long since noticed by Mr. Conybeare and Dr. Buckland, and running from Baglan, Swansea Bay, to Mynydd Eglwsilan, even brings up the lower beds of the coal measures at Maesteg and its vicinity (p. 189).* Three very marked lines of north-east and south-west ridges complicate this general east and west arrangement; one at Tair carn isaf, in the east of Llandibie, where a small trace only of carboniferous limestone is rolled into view within the general east and west lines of the coal field, another at Cribarth, Cwm Tawe, and the third above Pont Nedd fechan, Cwm Nedd, in the two latter cases ridges of carboniferous limestone penetrating a considerable distance within these lines. Contortions, and complicated undulations, as might be expected, follow the intermingling of these varied chief ridges. An inspection of the maps will show the complicated lines of coal crops in the neighbourhood of Llandibie. Though so complicated there, it is interesting to trace the manner in which the north-east and south-west anticlinal line merges into the east and west range of beds near Swansea. By carefully studying the ground, other equally interesting examples of the passage of the east and west lines into the north-east and south-west ridges, entering the coal field from the north, may be observed.†

The coal field of Dean Forest has been rolled into a position, where it has stood the denudation that has cut away its original connexion with the coal measures of Monmouthshire on the west, and we here observe the old red sandstone taking its range to the north, a direction still more

* This chief anticlinal line will be seen in the Horizontal Sections of the Geological Survey of Great Britain, sheet 10, sections 1, 3, and 4, and sheet 11.

† As these can be little understood by verbal description, it is intended to give a plate, when the survey of North Wales shall have been completed, in which it will be attempted to represent the various contortions and curvatures the older rocks have undergone prior to their denudation.

marked in the general line of the Malvern and Abberley Hills, on the north of which, near Coalbrookdale it unites with the range of beds coming round with a curve by Builth and Presteign, from their east and west course near Caermarthen.

We have evidence, therefore, that the old red sandstone, with its original covering, to a variable extent, of carboniferous limestone and coal measures, has been formed into lines even at right angles to each other, a kind of diagonal joining the southern and western ends. The general figure becomes thus a sort of rudely formed triangle, in which we observe numerous interior undulations merging into one another.

With the knowledge that in the S. E. of Ireland the older fossiliferous rocks were forced into north-north-east and south-south-west lines, anterior to the deposits of the old red sandstone of that country, a direction not improbably connected with the north-east and south-west, and other older lines in Wales, we are enabled to see that the range of the old red sandstone of the district noticed, and running in lines corresponding generally with this direction, would be dependent on a movement of subsequent geological date, since the dip of the beds on part of its course from the vicinity of Llangadock towards Builth, is far too considerable for such range to be merely consequent on the deposit of the old red sandstone on the flanks of the Silurian rocks previously raised, the whole being subsequently upheaved above the sea, as we now find it. A study, moreover, of the ground shows that both rocks have been rolled in the same lines, the force employed having acted upon them in the same direction. As far as the evidence extends the older rocks of the area including Southern Pembrokeshire, Southern and Eastern Caermarthenshire, Glamorganshire, Monmouthshire, Brecknockshire, Herefordshire, and Worcestershire, with parts of Shropshire and Gloucestershire, have been subjected to strong lateral pressure, acting unequally, or meeting with unequal resistances in various directions, after the accumulation of the old red sandstone, and probably also of the carboniferous limestone and coal measures, from which a complicated general figure, rudely resembling a triangle, has resulted. The trough of coal measures has been greatly contracted near Llanelly, on the west of Swansea, and steep dips and contortions are there seen;* but the greatest pressure upon them appears to have been exerted westward in Southern Pembrokeshire, where we have contortions of every description, amounting to complete reversal of the beds near Tenby.† The considerable uprise of beds which branches away from May Hill to Woolhope, where a bulging of the strata has upheaved the Silurian rocks, down to the Caradoc sandstone inclusive,

* See Horizontal Sections of the Geological Survey of Great Britain, sheet 7, sections 1 and 3. A section more eastward is given in sheet 8.

† Ibid., sheet 2, section 1.

shows the varied position into which the beds of the old red sandstone have been bent, as it would appear, contemporaneously.

Another complication of crumpled rocks, including the old red sandstone, carboniferous limestone and coal measures, extends from the southern part of the May Hill range to the Mendip Hills, by which a large triangular-formed patch of coal measures has been preserved, comprising the coal districts of Bristol, Cromhall, Newton, Faringdon, Radstock and Vobster. A strong east and west anticlinal runs across this triangular mass of coal ground, between Holy Trinity and Bristol, and many minor undulations are observable in it. The eastern range of the carboniferous limestone can be traced from Wickwar, by an isolated denudation near Wapley to the Week Rocks, and the curving up of the old red sandstone and carboniferous limestone near Frome, is in a direction as if the former line, coming from the northward, and the east and west strike of the Mendip beds, bending round by Frome, would meet beneath the overlaying new red marl and sandstones, and oolites near Bath.

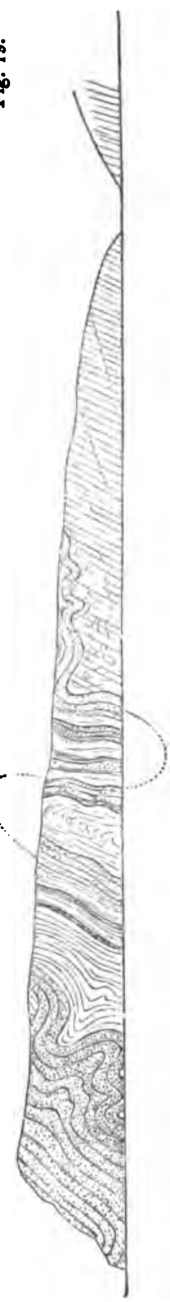
In the Mendip Hills the lines of undulation, the beds being unequally raised on the lines of elevation, so that elongated portions of old red sandstone appear through the carboniferous limestone, are more east and west than the general range of those hills would lead us to expect, several east and west anticlinal lines being observable between Shepton Mallet on the south, and Burrington on the north. At the same time there would appear a general range of the carboniferous limestone of the Mendip Hill towards the W.N.W. to join the arch of carboniferous limestone near Cowbridge in Glamorganshire, the carboniferous limestone of Barry and Sully Islands, with the limestone of the Flat and Steep Holmes, and of Whorl Hill and of Bream Down, showing the connexion.

The condition of the carboniferous limestone and coal measures beneath the covering rocks on the east, between May Hill and the eastern end of the Mendip Hills, near Frome, or on the south of those hills from Brean Down to Cloford and Nunney, must be much matter of conjecture. The island patches of carboniferous limestone, appearing from beneath the covering of more modern accumulations, still show undulating ground in east and west directions. It is a matter of no small interest to inquire respecting the extent to which the coal measures on the north of the Mendip Hills may be rolled in, as previously noticed (p. 213), to the southward of them, there being no geological reason that they should not be so rolled in.

The whole of the undulations of the old red sandstone, carboniferous limestone and coal measures, noticed as occurring in South Wales, in the adjoining English counties, and in Gloucestershire and Somerset,

those in the latter counties especially having been long since pointed out by Dr. Buckland and Mr. Conybeare,* more resemble adjustments to complicated pressure than to any prevailing lines of movement. As they are based on rocks which may have been crumpled before their deposit upon them, or ridged and furrowed in particular directions, some of these irregular movements may have been due to complications from very uneven resistances and pressure.

Fig. 19.



In addition to the horizontal sections of the Geological Survey, exhibiting contortions of various parts of the district, the annexed figures may be useful as exhibiting the crumpled state of parts of Pembrokeshire. Fig. 19 shows contortions of the Silurian rocks where they roll over northward at Dinas Head, near Fishguard, interesting also as exhibiting cleavage cutting through the beds, formerly clay or mud, beneath sands and gravels, the latter fossiliferous, without much affecting the sandstones and conglomerates.

While the Dinas section shows the contortions on the north, the following (Fig. 20) will exhibit an instance of curvature on the south, where the old red sandstone is rolled in a manner well seen on the coast.

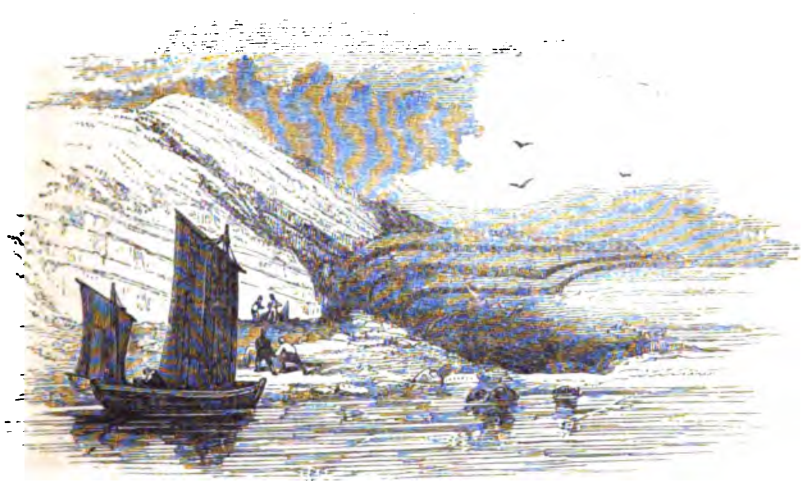
Fig. 21 will show contortions of coal measures in a central situation, on the north of Broad Haven.

Crossing over the interval covered by more modern deposits, we find, though there is a curvature of rocks, as shown by the limestones of Exford, Luxborough, Treborough, and Withycombe, and curved beds also on the south-east and north-east of the Quantock Hills, that there is a marked range of beds, much rolled into ridges and furrows, from Wiveliscombe on the east to Barnstaple and Ilfracombe on the west, the main direction being a few degrees north of west and south of east, not widely different from the main range of the Mendip Hills, and their geological continuation to Cowbridge, Glamorganshire. The same general strike is continued on the southward for a long distance into the carbonaceous rocks or coal measures of Devonshire and Cornwall, to Bude and

* Observations on the South-Western Coal Measures of England, Geol. Trans., Second Series, vol. i. In the map accompanying this memoir many anticlinal lines are laid down.

Fig 20.

Fig. 21.



St. Gennis, on the coast, and to the vicinity of Exeter on the east. Though the main direction of the great lines, with proper allowances for protrusion of lower beds more in one place than in another, is well marked, the contortions, as has been often observed, are of every form, and the minor flexures most complicated. Still further south we find the granite of Dartmoor, and around it we have evidence that it has not only burst through the Devonian series and the coal measures, cutting off some rocks from each other, but has also displaced a considerable mass of them, throwing them off along its flanks. An east and west line of strike is again observable on the south between Start Bay on the east and Bigbury Bay on the west, the gneiss and mica slate series of the Start Point and Bolt Head being continued westward to the Eddystone Rock.

Following the granite protrusions from Dartmoor to the Scilly Islands, there is little difficulty in seeing that the various stratified and contemporaneous igneous rocks of the Devonian series in that distance have been much modified in their range, if their lines of direction have not been altogether governed by the bosses of granite which have been thrown up between the extreme visible points of granite noticed. The range of these protrusions, including that of Dartmoor, may be taken as from E.N.E. to W.S.W., the various stratified rocks of the district being turned in the same direction as a whole, with minor local modifications.

The Lundy Island granite comes within the range of the Barnstaple beds, and if it should have influenced their continuation in that direction, the effects are concealed beneath the sea, except so far as regards the small patch of stratified detrital rocks found in the S.E. of the Island.

We have now to inquire how far the protrusions of the granite of Cornwall and Devon may have been connected with the movements of the old red sandstone, carboniferous limestone and coal measures above noticed, and how far the deviation of the South Devon and Cornish stratified rocks from the lines on the north may have been contemporaneous with the latter, or have been modifications produced subsequently to the formation of the main lines of contortion and rolls seen in North Devon. Although the protrusion of the granites is clearly after the deposit of the coal measures of Devon, its exact date, relatively to the succeeding accumulations, is not so obvious. Among the pebbles of the new red sandstone conglomerate nearest to Dartmoor, granite from it is scarce, some varieties having been only found on the north by Tawton and Stamford Courtney. As elsewhere* observed, the evidence of the uprise of the granite anterior to the new red sandstone series, consists in finding the latter quietly reposing upon the edges of beds which have certainly been thrown into their present positions by the protrusion of the adjoining granite, prior to their covering by that series.

That the upthrust of the Cornish and Devonian granites accompanied the contortion and crumpling of the beds in South Wales, in the adjacent English counties, in Gloucestershire, Somerset, and North Devon, it is not easy to prove. That the general disposition of the stratified Cornish and Devon rocks depends upon the protrusion of this granite, there would appear little doubt, and yet looking at the form of the coal-measure trough between North and South Devon there is a certain parallelism of its boundary lines on the north and south somewhat striking, making due allowance for the displacement produced on the south

* Report on the Geology of Cornwall, Devon, &c., p. 166.

by the granite of Dartmoor and of the Brown Willy range. The Devon and Cornish granites seem to have been thrust up through points of least resistance in a line extending from the southern part of Devonshire to the Scilly Islands, part having been protruded through the weakest places, and the remainder still concealed beneath, supposing this granite, connected below, at moderate depths, during the whole distance. This general line does not correspond with the range of beds in central or northern Devon. If the granitic rock, long since noticed by Mr. Horner,* be connected by means of the traces of an elvan dyke between Bull and Morte Points, North Devon, with the granite of Lundy Island, we have a line of bearing as elsewhere noticed,† corresponding with the general strike of the North Devon rocks, but we have no proof that the date of these granitic rocks is contemporaneous with the contortion and uplifting of the rocks among which they are found.

If we proceed to South Wales we find granitic rocks in Pembrokeshire, the largest mass on the north of the trappean range extending from Roche Rock to Trafgarn Rock, and a minor portion on the south of the trap extending from Bolton Beacon to the eastward of Troopers End, itself a mass of igneous matter apparently erupted after the deposit of the coal measures against which it abuts. This minor portion of granitic rock also seems of about the same date with another portion of erupted trap extending from the vicinity of Rosemarket to Benton Castle, and with another ranging through Walwyn's Castle to Goultrop Head, where that mass is distinctly seen to rise from beneath old red sandstone, overflow a small portion of carboniferous limestone, and abut against coal measures.

It may be desirable briefly to notice some of the igneous rocks of Pembrokeshire, since igneous action was there continued into a period corresponding probably with the granitic eruptions in Cornwall and Devon. We have seen that there is evidence of local igneous action at the time when the Silurian accumulations of Pembrokeshire were effected. The solid products vary from the rock which has borne the various names of compact felspar, cornean, petrosilex and some others, to hard compact and very fine-grained greenstone, and these may frequently be seen to graduate into each other.‡ We may often view the erupted mass as variably composed in its different parts, either of the

* Sketch of the Geology of the South-Western part of Somersetshire, Geol. Trans., first series. vol. iii.

† Geological Report, p. 186.

‡ As observed in a memoir written several years since, in conjunction with the Rev. W. D. Conybeare (On the Geology of South Pembrokeshire, Geol. Trans., Second Series, vol. ii. p. 1), Dr. Kidd was the earliest (1814) to give a good account of any of the Pembrokeshire trappean rocks, Geol. Trans., First Series, vol. ii. Many details of the Pembrokeshire trappean rocks will also be found in the former memoir.

same chemical elements, or differently constituted as regards them. To this original condition has been added that of having been differently circumstanced as respects cooling in different situations. The first would afford the power to form variable mineral substances, the latter that of obtaining them crystallized. When the compound consisted of enough potash or soda and alumina to form felspar, or albite, with only a portion of the silica present, it would form a rock to which the name of compact felspar, cornean, or hornstone would be commonly applied when circumstances were unfavourable to crystallization, or when the cooling was too rapid from the want of the necessary volume of heated matter; but when crystallization could be effected, felspar or albite would be produced, and the surplus silica appear by itself as quartz, so that the rock would be a compound of felspar, or albite, and quartz, one to which the name granitello has sometimes been given. In like manner with the other chemical substances forming the other minerals entering into the composition of these igneous rocks; thus greenstone would become syenite when, upon crystallization, there was a surplusage of silica, after the needful portion of the various silicates had been taken to form the minerals, felspar, and hornblende, and the same chemical elements mixed without these minerals being formed, would constitute a dark-coloured hornstone rock, quartzose in proportion to the amount of silica in it. Porphyries would be produced when any particular combination could be effected, forming a mineral crystallizing at a less heat than that which kept the other chemical constituents of the mass around in a fluid state, due allowance being made for any other power affecting crystallization.

In this manner we obtain an infinite variety of differences, observable often within short distances. Thus we have a rock looking like quartz rock, when the silica is abundant in it, as at Roche Rock; in its prolongation, within a mile or two, one apparently formed of so much felspar, that its decomposition constitutes a kind of porcelain clay; porphyritic cornean is found in the direction of Cuffern Mountain, where greenstone is also seen, and so on; even a porphyry resembling a Cornish elvan has been seen in the southern branch of this mass.

Between St. Lawrence and Brawdy we find a granite composed of felspar, quartz, and mica, the skirts of which, in the direction of Pant-yr-hafod, present the modification of a Cornish elvan, the cooling having been more rapid there than in the central portions, but towards Rhinderston it becomes difficult to say if the hornblendic rocks, there seen, be not a modification of the mass, of a kind similar to many observable in other igneous rocks of the country. This granite certainly seems to have altered the stratified rocks in contact with it in many places, but the date of its protrusion is uncertain.

The compound of felspar and quartz, near Waterless, Rosemarket, seems to merge into a rock in which hornblende largely enters, and we probably should view it as a mere crystallized condition of the many felspathic trap rocks, as they are sometimes termed, which graduate into syenites and greenstones, and we may not be far wrong in assigning it an age subsequent to the deposit of the adjoining old red sandstone, forming a part of a system of igneous eruptions posterior even to the formation of the adjacent coal measures. The igneous rocks of Gouldtrop Head vary from common greenstone to syenite, as there may or may not have been a surplus of silica beyond that required for the silicates in felspar or hornblende, and there are some hornstone and other trappean varieties observable in its continuation to and beyond Walwyns Castle. The igneous rocks between Bolton Beacon and Troopers End are also variable. Near the former we have greenstone, sometimes approaching a porphyritic character, from disseminated crystals of felspar; at Johnston, however, there has been a greater abundance of silica, and quartz becomes mixed with the felspar and hornblende, forming syenite, and this continues eastward to Troopers End, greenstones still being here and there observable. In the mass of trap between Waterless and Benton Castle greenstone somewhat prevails; but crystallization being imperfect, the hornstone form of rocks is found at Benton Castle, on its eastern extremity.

The granite of Cornwall and Devon usually presents a common character, one from which we may infer that the component parts have frequently been such that, under favourable circumstances, large crystals of felspar have easily separated from the other substances which constitute the surrounding mica, felspar and quartz, in the same manner that crystals of felspar are observed disseminated amid a confused crystallization of felspar and hornblende, in porphyrytic greenstones. This granite is also often schorlaceous, especially on the outside portions of many masses. The mica varies from black to white, and Dr. Turner found lithia mica as well as that of the common kind in the Cornish granites. A passage of the ordinary granite into the compound formed of quartz and schorl, named schorl rock, may frequently be observed. Though the mica usually disappears as the schorl prevails, this is not always the case. The mica commonly first disappears in this passage, and then the felspar, leaving the quartz and schorl, the latter sometimes forming a radiating nest of crystals in the former.

In the granite district of St. Austell a variety prevails into which a steatitic or talcose mineral largely enters, and mica is more rare. This granite is very liable to decomposition, and is extremely schorlaceous at its junction with the slates from St. Mewan's Beacon to Roche, elongated stripes of schorl rock (schorl and quartz) protruding among the slates.

Alternations of schorl rock and granite are observable on the south of Carglaze Mine. An interesting variety, lithologically, occurs in places, as near Meladore, where crystals of felspar are found in schorl rock, some of these crystals decomposed and the cavities so formed partly filled with schorl. The Land's End granite contains much schorl, though the triple aggregate of mica, quartz and felspar, rendered porphyritic by large crystals of felspar, is sufficiently common. The granite of the Scilly Islands is formed of the usual triple compound, and schorl appears rare. Schorl veins are found in the granite of Kit Hill and Hingston Down, between Dartmoor and the Brown Willy range, and schorl rock graduates into the granite of Belovely Beacon, north of the Hensborough mass, so that schorl may be fairly regarded as a marked additional mineral to the ordinary triple aggregate of the Cornish and Devon granites.*

The Devon and Cornish granites, as elsewhere noticed, may be regarded as masses of matter (when schorl is absent) composed of silica, alumina, potash, magnesia, lime, oxide of iron, oxide of manganese and fluoric acid; lithia being occasionally substituted for the latter. Of these ingredients silica is the most abundant (about 73 to 75 per cent.), alumina follows next (13 to 19 per cent.), and potash succeeds (8 to 9 per cent.). The other substances are very subordinate, the most abundant, oxide of iron, being about two per cent.† When schorl forms part of the granitic masses, and it is not uncommon in many, boracic acid and soda are added to the other ingredients. Indeed it is not improbable that the soda felspars, or albite, may more frequently occur than is supposed. The schorl varieties being more common on the flanks of the masses, generally, the boracic acid is thus found chiefly on the outside parts adjoining the rocks through which the granite has been forced; a point of much interest. In schorl rock composed of about equal portions of schorl and quartz, the silica would appear in less proportion than in the common granite, calculations giving us about 67 per cent. of that substance, the alumina remaining nearly the same (18 per cent.), and the amount of oxide of iron being increased (nine per cent.). This decrease of silica generally, though the proportion of quartz is so large, arises from the minor quantity of silica required for the schorl (35 per cent.).

When we observe the mode in which the granites of Cornwall and Devon have been brought into their present position, it is evident that they have not been intruded in the manner so common among the trappean rocks previously noticed. We have nothing resembling the accu-

* A detailed account of these granites will be found in the Geological Report of Cornwall, p. 156-192; as also in the memoirs of Mr. Carne, Dr. Boase, and other authors, in the Transactions of the Geological Society of Cornwall, and in Dr. Boase's Treatise on Primary Geology.

† See the calculations, Report, &c., pp. 188, 189.

mulation of ashes or cinders, nor the lines and masses affording sections like those of upturned lava streams or sheets of matter ejected from craters, and widely covering subjacent detrital or calcareous accumulations.

From the Scilly Islands to Dartmoor inclusive we seem to have the upthrust of one mass, which found points of less resistance amid the superincumbent accumulations, more in some places than in others. Where such presented themselves, and the granite could be forced through, there was much displacement of these accumulations, and they were squeezed into forms in accordance with the varied degrees of pressure exerted upon them. As the masses arose the edges of the detrital, trappean and calcareous beds against which they pressed were frequently fractured, and into the fractures the granitic matter was forced, forming the granite veins, as they have been termed, which can often be traced terminating in somewhat fine threads, so that not only was the pressure great, but the fluidity of the igneous rock sufficient to pass into small cracks and rents. As masses the protruded granites must have possessed no small power to overcome the resistances opposed to them, resistances of no slight order when we view the bent and contorted forms into which the adjacent sandstones, slates, limestones and trappean rocks have been forced. Thus, though from the enormous pressure exerted, the granitic matter may have been driven into somewhat small fissures in the adjacent rocks, there was a cohesion of parts sufficient to force rocks asunder across their line of bearing, their strongest lines usually, as appears to have been the case to a certain extent on the east and west of Dartmoor, and to thrust them aside, bending and contorting their beds in a manner implying the exertion of great power.

It could but be expected that from great heated masses of this kind being thus brought into contact with the detrital and other beds (the pores of which, whether the rocks were above the sea, or beneath it, full of moisture), great modifications of such rocks would be effected, in accordance with the mineral or chemical composition of the bodies so acted upon. We have seen that a large portion of the detrital accumulations are such as may be considered as having been derived from abraded granitic rocks, the slates for the most part having been clays to which decomposed felspar furnished the chief part, the sandstones, principally abraded quartz, variously mingled with the triturated parts of pre-existing siliceous rocks of different kinds, and the arenaceous slates, variable compounds of these sands and clays, mechanically worn fragments of mica being often abundant in such arenaceous slates and sandstones. According to the composition of these rocks, including the matter cementing the sands, or other finer particles together, have been

the alterations. The slates, when formed of clay, containing a large proportion of silicate of alumina, the remains of the felspars in the granites, whence it was derived, are often seen turned into an impure kind of porcelain, noticed as happening from the contact of similar beds with the igneous rocks of a former period near Builth. Trappean rocks brought into juxtaposition with the granite show, by their alteration of structure, that there has been a new adjustment of particles. Many have been placed under conditions as if they had been longer cooling originally, and a larger grain is observable near, and in contact with, the granite. In a few instances the arrangement of parts has been such as to present a new form of mineral, and hypersthene appears instead of hornblende, as at Corks Tor, and some other places on Dartmoor.

The granites are occasionally observed to be traversed by veins of granite, usually of smaller grain, such veins not confined to the granite, but extending into the adjacent rocks. In this case we appear to have evidence of a cracking of the main mass of granite upon cooling. These cracks sometimes extended into the adjoining rocks, interlaced by previous veins, and held in firm contact with the main body of granite, so that a granite vein may be observed to traverse the outskirts of both the main mass of granite and these adjoining rocks. The granite still fluid beneath this cracking of the surface and sides, would be forced into the new fissures, where it would crystallize according to the conditions to which it would be exposed. Judging from the grain and the size of the veins, there would appear to have been still heat enough in the granitic mass to retard the cooling, so that the matter in the veins did crystallize, though usually in a small grain. In the sections afforded of the granite of the Scilly Islands, well exhibited among its numerous rocks and isles, many of these veins, cutting through the chief mass, are exhibited.

As the cooling proceeded, other cracks or fissures appear to have been formed, of a large size however, and showing the presence of granite beneath, in situations not exhibited by the main masses above mentioned. To the granitic matter filling these fissures the Cornish miners have given the name of Elvans, a convenient term, since though we may regard their composition as chemically the same in any given locality, their lithological character will differ, in a section across them, from good crystallized granite to a compact siliceo-felspathic rock, without crystallization. From being extensively quarried for economic purposes, the multiplied sections of them, thus exposed, afford the best opportunities for studying the modified effects produced by the cooling of igneous rocks under variable conditions with which we are acquainted. When we examine the walls of these granitic dykes, for such they are, there is rarely evidence of any fault having been formed, but rather of a crack, usually ranging in a long line,

as if there had been tension, a rending of solid rocks in consequence, and an uprise of granitic matter in fusion from the necessary pressure upon a mass of such matter beneath. It is interesting to observe that when circumstances have permitted good crystallization, the granite formed corresponds generally with the mass adjacent to it, as if such matter had been prolonged beneath, retained in fusion until the needful fissure was formed, and then forced up into it.

The central parts of these granitic dykes are, as might be anticipated the crystalline portions, when the necessary conditions have obtained, on each side of which the porphyritic character is found, followed outside these again, towards the walls of the separated rock, by the more compact rock, without crystallization. The modifications are of every kind from local conditions; frequently the porphyritic form fills the whole fissure, occasionally even that amount of crystallization appears not to have been effected, and a compact, or even soft, variety is seen.*

By reference to the Geological Maps of the survey, it will be observed that the elvans hold various courses, and that, though seldom exceeding 300 or 400 feet in breadth, most commonly far less, they can be sometimes traced satisfactory for many miles. One can be so followed for twelve miles, from near Marazion to Pool; a branch, five miles long, being thrown off by Carnhill Green into the Carnbrea granite. The elvans are clearly formed after the protrusion and consolidation of the granite masses, since the latter are traversed by them equally with the older igneous and detrital rocks, the same elvan cutting through them all. Among the examples of elvans branching off into two or more lines, the best would appear to be that found in the Carn Menelez granite, where, radiating from a point in that granitic boss, several of these granitic dykes cut through outwards into the slate district between Penryn and Gwennap. Another example of radiating elvans is to be seen in the Penzance and Marazion district.

To account for the filling of the fissures into which the granitic matter of the elvans has been introduced, in one or two instances at least, as at Pentuan, with sufficient force to break away the adjacent sides, and carry up included fragments of the traversed beds so broken off, more particularly near the walls of the dyke, we may look to some minor exertion of the same force which propelled the granite upwards in mass previously. Among the lines into which the sedimentary rocks had been bent, many lines of least resistance would be offered for cracks or fissures, into which molten matter from beneath would be injected from the relief of

* A detailed account of the Cornish and Devonian Elvans will be seen by reference to the Report on the Geology of Cornwall, &c., p. 173-186.

the necessary pressure upon it, so that rents being produced, the granite would be thrust upwards. We observe that elvan courses keep such lines in many instances, the range of two or three between Redruth and Penzance, running in the same strike with the detrital and igneous rocks of prior geological date, as may easily be observed in the geological maps. In these cases, however, the adjustment is more to general lines than to any position which could be mistaken for contemporaneous interstratification, as they are well seen to cut through many of the associated beds, more particularly in their passage from beneath upwards. The most marked case of an elvan which does not seem to adjust itself to the general course of those which more or less exhibit lines of direction, having a tendency to connect bosses of granite, or run in a general manner amid the stratification of the detrital rocks, is that traversing the country for many miles north and south, from Watergate Bay towards Michell, crossing the beds for the most part at right angles.

The extent to which these elvans, and consequently the fissures through which they have risen, may have been geologically of the same date is difficult to prove. It is clear that at least many of them were formed after the protrusion and consolidation of the granite for a considerable depth. The granite veins which cut the serpentine and hornblende slate of the Lizard district may perhaps be referred to the same date, but amid all the conditions under which the granite masses of Cornwall and Devon may have originally struggled to find a passage through the body of superincumbent detrital, calcareous, and igneous rocks of earlier date, many a rent or fissure may have been formed, into which granitic matter was then injected, difficult in after times to separate from the granitic dykes, cutting the great granite bosses, themselves sufficiently consolidated for a considerable distance from the surface to split and break.

As we have not hitherto observed any overflowing of the granitic matter, out of the elvan fissures, and can scarcely imagine that the resistances and pressure could be so nicely balanced as always either to bring the molten rock up to the margin of the fissure, or not to overflow it, we may probably look to the great denudation which this part of the district has experienced as well as others, for the cutting away of any overflows, should they have occurred, or down into the cracks partly filled. Mining operations would occasionally appear to show elvans which do not reach the present surface.

When we look at the uplifting, flexures, or contortions of the Silurian, old red sandstone, Devonian, carboniferous, or coal measure rocks of our district, and it may be desirable to extend our view into North Wales and adjacent English districts, in which these rocks are also exposed, it does

not appear, from any surface evidence observed, that displacement caused by the protrusion of granite, or other igneous rocks, is adequate, by lateral thrust, to produce the crumpling of, and diminished area occupied by, those accumulations. If there be such causes beneath the covering of more modern deposits on the east, we possess no evidence of them.*

When the disturbance caused by the upburst of the Cornish and Devon granite may have ceased to have been felt, and how far this event may have been connected with an early or a late movement of the various rocks previously formed to the end of, at least, a large part of the coal-measure accumulations, it may be difficult to define geologically. There is evidence in our district to show that, anterior to the accumulations to be next noticed, and when comparative tranquillity was apparently restored, great dislocations or faults were produced, crossing the bent or contorted beds, and pointing to a further settling, as it were, of the area which had been so violently disturbed. It is well known that some of the faults in the Bristol and Radstock coal districts, affecting the coal measures, do not traverse the superincumbent dolomitic conglomerate of the new red sandstone series. A marked instance of this kind is seen at Radstock, where, at Clan Down colliery, a considerable fault is covered quietly by nearly horizontal beds of the new red sandstone and oolitic series. The same fault has been found again on the southward of Radstock, beneath undisturbed beds of the like kind, and can readily be traced across the coal measures near Vobster, and the old red sandstone of the adjoining continuation of the Mendip Hills, to the south, where, with others, it is covered over by undisturbed inferior oolite.†

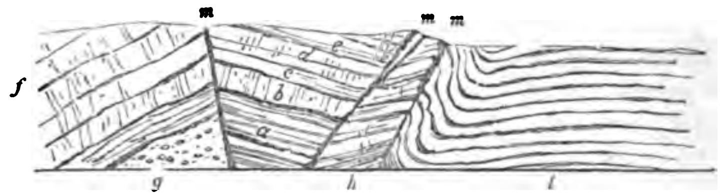
Another good example is seen at the Week Rocks, where a considerable fault lets down sandstones, with coal beds, on the east of the carboniferous limestones there exposed, yet this fault does not affect the dolomitic conglomerate and lias which surround this patch of older rocks, as it were in a frame. Other cases could be adduced, but these will be sufficient to show the fact. These faults, and several others, extending through the Bristol coal field, and beyond it into the Silurian rocks of Tortworth, have a north and south course; but it would be hazardous thence to infer that all those having the same direction in our district have the same date, since in Glamorganshire we have northern and southern lines of fault, traversing rocks up to the lias inclusive. The following is the

* More continued research will decide the point; but at present the granite of the Wicklow and Wexford mountains, on the opposite coast of Ireland, which may be supposed to have aided in forming, by lateral pressure, some of these flexures and contortions, could scarcely have effected those movements observable in the old red sandstone, carboniferous limestone, and coal measures, since, as the existing evidence tends to show, these rocks were formed after the upthrust of that granite.

† See Ordnance Maps of Great Britain, coloured geologically, sheet 19.

section of one where it abuts upon the sea to the eastward of Sully Island, Glamorganshire.

Fig. 22.



a, earthy, variegated, dolomitic limestone and marl; *b*, compact dolomitic limestone; *c*, red earthy limestone; *d*, compact dolomitic limestone; *e*, mixed earthy, red, and light coloured dolomitic limestone; *f*, compact dolomitic limestone; *g*, dolomitic conglomerate; *h*, beds generally similar to those in the left; and *l*, lias; *m m m*, faults; those on the right, or east, being interesting, as deviating from the more common arrangement in which the plane of the fault dips towards the downthrow, or rises to the upthrow. As the planes of the faults on the east and west would probably meet beneath at no great depth, we may regard the mass between them as a mere wedge, jammed in at the top, the great dislocation being continued on the line of the left or western fault.

The northern and southern lines of fault traversing the coal measures of Glamorganshire and Caermarthenshire are most marked (see Geological Maps). A multitude of them are seen in the west of Swansea, some extending across the carboniferous limestone of Gower, sections of which are well exhibited on the sea coast. How far these may correspond in geological date with those found in the Bristol coal fields and the Mendip Hills, is by no means clear. They range in the same direction as those in Cornwall and Devon, known as cross courses, from traversing and often heaving the metaliferous veins of those counties. The latter having evidently been in many cases, and probably in all, formed with much, at least, of their ores of copper and tin, and sometimes of lead, before the cross courses were produced, since the veins are cleanly cut off by them, many having been again worked on the other side of these faults. The same uncertainty prevails as to the geological date of the interlacing of faults seen in the Monmouthshire coal field, some of which have an eastern and western direction. There are many faults clearly of a date posterior to the formation of the new red sandstone series, of the oolites, and even of the chalk. Of the former many examples are seen in Devonshire, a marked one extending from near Broad Clist several miles westward, and bringing down new red conglomerates and sandstones against the coal measures of that part of the country. Others will also be observed in the same neighbourhood. East and west faults are well seen near Bridgwater and Watchet, traversing new red marls and lias. In Glamorganshire there is a good case of eastern and western faults, letting in lias and new red sandstone and marls, between Pyle and

Coity, so that in a very moderate area, geologically considered, in Glamorganshire, we find eastern and western, and northern and southern faults, traversing rocks up to the date of the lias inclusive.

The eastern and western fault, ranging from across the oolites on the north of Bath, into the coal measures on the west,* was certainly produced after the northern and southern faults, covered quietly by the new red sandstone and oolitic series of the same country, and above noticed. In like manner the considerable east and west fault which, crossing close to Meer, in Wiltshire, there throws the lower chalk into contact with Kimmeridge clay,† and thence traverses the oolites near Wincaunton, must be of later date than the north and south faults of the Mendips, covered quietly over by undisturbed inferior oolite, near East Cranmore. A still closer example of this fact is seen in the east and west fault, traversing the oolites from Wanstrow, by the north of Batcombe and the south of Chesterblade, which must cut across these north and south faults, traversing the Mendips. We thus appear to arrive at the conclusion that lines of direction alone will not suffice for safely assigning a geological date to those faults which may correspond with the lines so clearly seen in the Bristol district, and in the Mendip Hills, since there have been fissures taking the same general direction at other times, as also east and west faults of different dates, even within this district.

Poicilitic or New Red Sandstone Series.

Whatever inequalities may have existed at the close of the geological period last mentioned, and whatever geological time may have been required for the contortions, undulations, and crumpling, to which the rocks then formed have been subjected, a period now arrived when the accumulations in this district, to the chalk inclusive, were arranged much as we find them relatively to each other, disturbed only by faults, and a few large flexures or undulations, such as the wide arch, including the chalk, prolonged from the Mendip Hills eastward to the Wealden district, the uprise of which was not improbably effected at the same time with the arched and bent beds in the vicinity of Weymouth.

In 1816, Mr. Warburton observed, respecting the conglomerates and associated new red sandstone beds in the neighbourhood of Bristol and the Mendip Hills, that "if denudation or other disturbing causes were in action previously to the red marl, we might expect to find the red marl immediately incumbent upon any rock from the coal measures to the granite inclusive, just as the alluvial beds in which the bones of elephants are found, in consequence of previous denudation, are discovered resting

* See Horizontal Sections of the Geological Survey of Great Britain, sheet 15, section 1

† Ibid., sheet 17.

on the blue clay of London, upon the Oxford oolite, or any other bed."* In 1822, Dr. Buckland and the Rev. W. D. Conybeare showed that not only were the older and disturbed rocks of this district covered unconformably by various beds of the new red sandstone series, but also that the lias and inferior oolite were brought into contact in the same relative position with them.†

The lowest part of the poicilitic, or new red sandstone series, in our district has generally been considered as composed of a conglomerate formed of rounded portions or fragments of the subjacent rocks, cemented by carbonate of lime, mixed occasionally with so much carbonate of magnesia, that the name magnesian conglomerate was applied to it, and magnesian limestone to the limestone into which it sometimes graduates by the disappearance of the pebbles of the subjacent rocks, and the presence of little else than the matter of the cement. Instead of these terms the names of dolomite conglomerate and limestone were suggested by Dr. Buckland and Mr. Conybeare, they at the same time observing, that the cement, or limestone, in the absence of pebbles and fragments, was sometimes dolomite (carbonate of lime and magnesia) mixed with carbonate of lime, at others merely carbonate of lime. They also pointed out that the pebbles and fragments in the conglomerate, or breccia, were those of the nearest hard rock, fragments of coal sandstones being scarce, probably from their texture being commonly too friable to resist the friction to which the other pebbles had been exposed.†

Upon carefully comparing the facts observable in connexion with these conglomerates and limestones, from the vicinity of Pyle and Newton, in Glamorganshire, to the Mendip Hills, in one direction, and to the neighbourhood of Chepstow, Monmouthshire, and Tortworth, Gloucestershire, in another, there appears reason for concluding that such conglomerates and limestones may have been of different dates, though included in the period during which the new red sandstone series was deposited, as also that the cause of their production continued up to, and included the base of the lias. They in so many cases resemble consolidated beaches, and also in so many cases occur as such beaches should do, that we have probably before us similar lithological results, produced by a continuance or repetition of similar causes during

* Note on Magnesian Breccia, Geological Transactions, First Series, vol. iv. p. 205.

† Observations on the South-Western Coal District of England, Geological Transactions, Second Series, vol. i. p. 217. Dr. Buckland and Mr. Conybeare observe, that, "from the total want of conformity between the two series of rocks, we have already deduced the consequence, that the lowest of the overlying deposits may be placed in contact indifferently with any one of the inclined rocks. We may now deduce the still more general consequence from this want of uniformity, that any member of one series may be in contact with any member of the other." p. 218.

† Geological Transactions, Second Series, vol. i. p. 291.

all the geological time comprised between the commencement of the new red sandstone series, and the base of the lias inclusive. The chief difference is that, at the latter time, the abundance of peroxide of iron, sufficient previously, during the period of the new red sandstone series, to give much colour to the cement of many of the conglomerates, had disappeared. Moreover, certain organic remains, found in the lower beds of the lias, are intermingled occasionally with its conglomerate, so that this conglomerate can scarcely be mistaken for the other, though due to general similar causes.

Dr. Buckland and Mr. Conybeare have shown that the dolomitic conglomerate "generally forms a thick bank, or talus, near the base of those hills, from whose debris it has been derived; while, at a distance from them it grows thinner, and at length wholly disappears."* When we trace the conglomerate up the sides of sufficiently rising ground, as, for instance, in many situations on the flanks of the Mendips, where the associated sandstones and marls have not been removed by denudation, we find that this mode of occurrence is at times repeated, as seen in the following page, parts of one of the large horizontal sections of the Geological Survey;† so that we have to suppose a filling up by the red marls, and then an intermingling of a beach-like wedge from the adjacent land, and this repeated.

It will be obvious that when denudation may have removed this evidence, a surface, formed along the line *d d*, Fig. 23, would appear a mere common coating of the conglomerate. The consolidation of beaches, by carbonate of lime, now takes place in many localities where waters charged with the bicarbonate percolate through it.

It will be evident that whenever conditions may arise for the deposit of the carbonate of lime, or of carbonate of lime and magnesia, as the case may be, without including the pebbles, the travertino, for such it would be, would cover up the conglomerate beneath. In supposing, therefore, that these dolomitic conglomerates may often have been beaches skirting the land of the time, rising higher and higher up its flanks as such land became depressed relatively to the sea,‡ we do not suggest a mode of explanation at variance with the manner in which such things may happen at the present time, but, on the contrary, one in accordance with it.

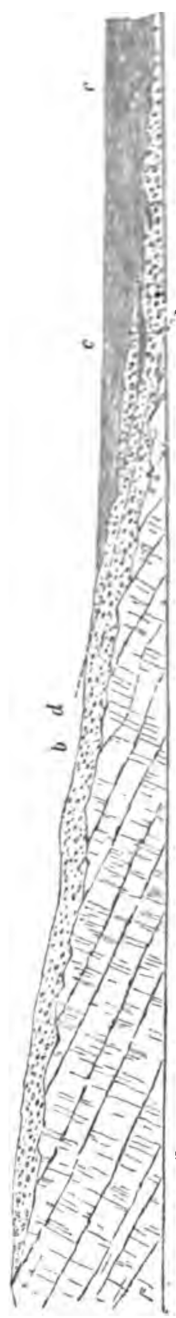
* Observations on the South-Western Coal District of England, Geological Transactions, vol. i. p. 293.

† Sheet 17.

‡ A supposition necessary for the accumulation of the various rocks of subsequent date in this vicinity.

Fig. 23.

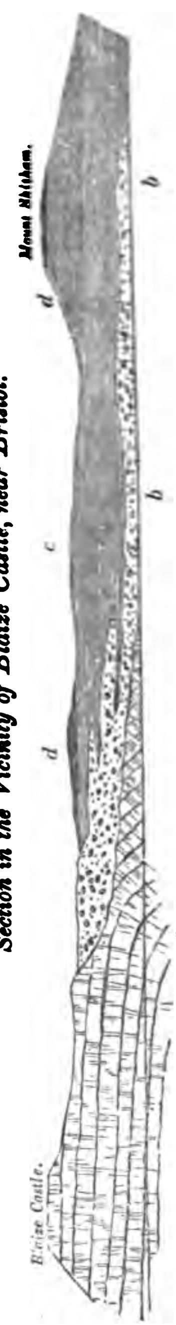
Section of the North Side of the Mendip Hills, near Compton Martin.



a a a, carboniferous limestone; *b b b*, dolomitic conglomerate; *c c*, new red marls.

Fig. 24.

Section in the Vicinity of Blaize Castle, near Bristol.



a a, carboniferous limestone; *b b*, dolomitic conglomerate; *c c*, new red marls; *d d*, lias.

To enable the eye readily to perceive the manner in which these conglomerates and limestones occur relatively to the older rocks, now exposed to view, they have, in the accompanying map (pl. 2), been tinted so as to effect this object. The fringe to the older rocks, which they often form, may in this way be easily seen, and standing on any of the high grounds, on the Mendip Hills, for instance, it is interesting to consider how exactly they occur, as they should do, under the supposition that they have been beaches among islands, rising above the sea of the time. Finding these conglomerates, even at considerable altitudes, accords with this view, the islands becoming less as they disappeared beneath the sea level, and the portions of land last brought within the action of the sea being, like those at lower levels, equally, and indeed often more, exposed to the force of the breakers of the time, since there was, gradually, less adjacent land to afford protection.

Much of these conglomerates is no doubt concealed beneath superincumbent red sandstones and marls, well proved by the pits and other workings in the collieries of many parts of the Bristol district, particularly towards Radstock and the Mendip Hills, where they are known by the name of millstone grit, millstones having been made of them. When, however, carefully examined, these conglomerates still suggest the idea of adjacent and subjacent rocks worn down by breakers, and strewed over the bottom and sides of cavities by their means, such calcareous, or magnesio-calcareous matter as may enter into the cement of the pebbles, or fragments appearing to require a certain amount of subsequent tranquillity, for a time at least sufficient to be introduced among, and join the pebbles and fragments together. As the conglomerates are sometimes observed layer above layer, this consolidation may have taken place at intervals in such situations.

At Kenfig Point, Glamorganshire, we find the most western patch of dolomitic conglomerate and limestone above the surface of the sea, the beds variable in texture, the cement of the former prevailing sometimes more than at others, forming limestones, and the structure of both occasionally exhibiting holes, in some of which agates are found, the whole resting upon the upturned edges of carboniferous limestone. Hence to the eastward (see Map) many other patches of conglomerate and limestone are observed, the former often thick, as at near Coity, where it forms a very beautiful rock in several beds.* Near Llanhary, and from thence to the south of Llantrissant, the conglomerate is observed to cover both the carboniferous limestone and coal measures, and an outlying portion is observed near Llanharan reposing upon the latter. In all

* When cut and polished it forms a good marble, specimens of which may be seen in the Museum of Economic Geology. When free from pebbles of sandstone the conglomerate of this and other localities is worked for lime.

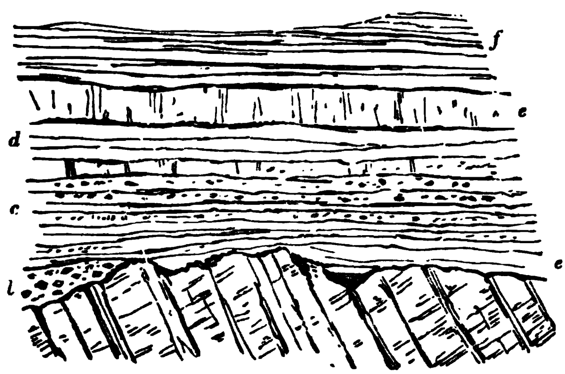
these situations the character of the accumulation is much the same, pebbles of sandstones being more mingled with those of limestone near the coal measures. After looking at the relative positions of these various patches to the older rocks, a strong impression is made that the adjoining heights of the coal measures were above the surface of the sea, while these conglomerates and limestones were forming, and that the old red sandstone and carboniferous limestones of the lower and southern part of Glamorganshire occurred as low rocks and islands exposed to the action of breakers, which ground down the softer rocks, and partly formed the harder into shingles, the latter consolidated, for the most part, by magnesio-calcareous, or simply calcareous matter. Occasionally there was less exposure, and when this occurred red marls and sands were intermingled with the conglomerate, and many bands of limestone, often impure, could be produced. One of the Geological Survey sections, across part of this country, will best exhibit the mode of occurrence and variation of some of these deposits.*

On the coast, where the junctions of the dolomitic conglomerates and limestones, resting upon the carboniferous limestone, are well seen, we have occasional instances where the fossils of the carboniferous limestone have been, by the combined action of the sea and atmosphere, as they are at the present day, brought out in relief before the finer varieties of the dolomitic limestones were accumulated upon them, so that they were enveloped by the former, and without due care, might be mistaken for carboniferous species existing at the time of these limestones. In some cases we have taken out fossil corals, which have been quite detached from the subjacent rocks, and but little injured, as if in the many localities where abundant loose and separate fossils had occurred (encrinites, and shells, both occasionally as perfect as when first preserved in the carboniferous rocks, close to coasts, but above the washing of the sea), there had been just sufficient action to remove the soil, beneath which these fossils are so often in multitudes, and, during a general depression of the land, relatively to the sea level, so as to incorporate them quietly in the newly-forming limestone.

Many localities, where the deposits were formed in comparative repose, are now necessarily, from denudation, faults, and various obvious causes, cut by the coast line, so that we may advantageously study them. Of this kind the following section at Barry Island may be considered as instructive.

* Sheet 11, which contains a section from the Bendrick Rock, near Barry Island, to and across the coal measures on the north, extending to the old red sandstone of Allt Llwyd, Brecknockshire.

Fig. 25.



a a, upturned beds of carboniferous limestone; *b*, breccia, composed of fragments of subjacent limestone, cemented by a cream-coloured dolomitic limestone; *c*, red earthy dolomitic limestone, frequently containing fragments of subjacent carboniferous limestone, and in part marly; *d*, greenish-white dolomitic limestone; *e e*, cream-coloured dolomitic limestones; and, *f*, red marl, containing bands of dolomitic limestone further east.

This section exhibits but little evidence of any but somewhat tranquil action, a mere deposit of red mud, such as might readily be held in mechanical suspension, intermingled with magnesio-calcareous matter, held in solution in the same water. The breccia is such an union of fragments as may readily happen in many a sheltered nook, or arm of the sea, at the present day, where no breakers of sufficient magnitude to round any such fragments, strewed on the shore, fall upon them. While the land descended gradually beneath the sea, its configuration must often have offered the needful conditions, judging from the inequalities shown to have existed, and now preserved beneath coatings of these deposits, and of others of red marl and sandstone, often covered by lias. Indeed, by studying these inequalities, so easily observed, we have no want of localities where deposits of this kind would have been modified according to the conditions presented. There would sometimes have been an open coast well exposed to breakers, where boulders and pebbles abounded, at others there would have been sheltered situations, where the same matter which often bound such boulders and pebbles together, merely cemented small angular fragments of older rocks, or formed beds of limestone, occasionally mingled with any light matter held in mechanical suspension by the same waters, and thrown down in quiet places with it. As the land continued to descend, various modifications would take place, and thus a variety of minor alterations of particular kinds of deposits would be produced.

After passing the neighbourhood of Llandaff and Nadir, we lose the

dolomitic conglomerates and limestones until we arrive at the carboniferous limestones towards Undy and Chepstow. How much of these rocks may be buried beneath more modern accumulations, including the broad alluvial tract skirting the shores of the Bristol Channel, between Penarth and Chepstow, it is difficult to say. Crossing from the vicinity of the latter place towards Thornbury and Tortworth, we find the dolomitic conglomerates and limestones resting either upon the old red sandstone or carboniferous limestone. In the neighbourhood of Tortworth, the beach-like character of the conglomerates is well exhibited. We see, as it were, the lines of beach still remaining at their relative levels round the nose of older rocks facing the north, the mud and sand of the period, then forming the bottom seaward, having been removed by the denudation which has here opened out so much subjacent ground, and left escarpments of the oolites on the east, standing like cliffs abandoned by the sea.

In the country around Bristol there are abundant opportunities for observing the varied manner in which the dolomitic conglomerates and limestones occur, resting upon old red sandstone and carboniferous limestone, as the case may be. Many details respecting them have been given by Dr. Buckland and Mr. Conybeare,* Dr. Bright,† and other geologists. The conglomerate of the Vale of Westbury is pointed out as containing an abundance of sulphate of strontia, forming part of the matter cementing the pebbles and fragments together. The frequent occurrence also of nests of sand in many places, the irregular cavities filled with rock crystal, chalcedony, carbonate of lime, and other minerals, and which, when detached from the matrix surrounding them, are locally known as *Potato Stones*, from their external resemblance to that tuber, is mentioned. These cavities, so filled, and shown to be particularly abundant near Mells (Mendip Hill district) are of the same kind as those noticed above at Kenfig Point, Glamorganshire, and are occasionally observable in many parts of the general district, where the dolomitic conglomerates and limestones prevail.

The annexed section, showing the manner in which the dolomitic conglomerate and limestone repose on the upturned edges of carboniferous limestone in the Avon section will illustrate the mode in which a beach-like accumulation becomes covered by beds gradually partaking upwards of the character of limestones. The section is exposed on the cutting of the new road from Clifton Downs to the Hotwells, and can be readily seen, *a a* being the upturned higher beds of the carboniferous limestones, containing sandstones and marls, brought down by a great

* Observations on the South-Western Coal District of England, Geol. Transactions, vol. i. pp. 212, 291-294, &c.

† Geological Transactions, First Series, vol. iv.

fault on the north of the Windmill Hill; *b*, boulders and pebbles (in part subangular) of carboniferous limestone, some of the former not much less than three tons in weight, cemented by matter variably consolidated; *c*, conglomerate or breccia, in which the magnesio-calcareous cement is more abundant; and, *d*, where it becomes still more so. Further to the right, in beds above those exposed in the annexed section, the fragments of carboniferous limestone, commonly angular and small, are rare, so that the magnesio-calcareous matter constitutes nearly horizontal beds of dolomitic limestone. These beds are continued into the country in a manner to show that, although there may here have been a minor depression between the Clifton Hill and Durdham Down on the north, the dolomitic limestone and conglomerate seem to have overspread this portion of ground, after the great inequality, produced by the fault above mentioned, had been worn down, covering up a portion of it. Such wearing down of asperities thus produced appears to have been common. Some may have required more time than others, and many of those considerable inequalities of surface in the old red sandstone, carboniferous limestone and coal measures, portions of which still protrude through their covering of more modern accumulations, may originally have been caused by faults. That there was great destruction of these older rocks may be seen by consulting the sections across the Mendip Hills and Bristol district,* and their rolled and fragmentary remains, with all

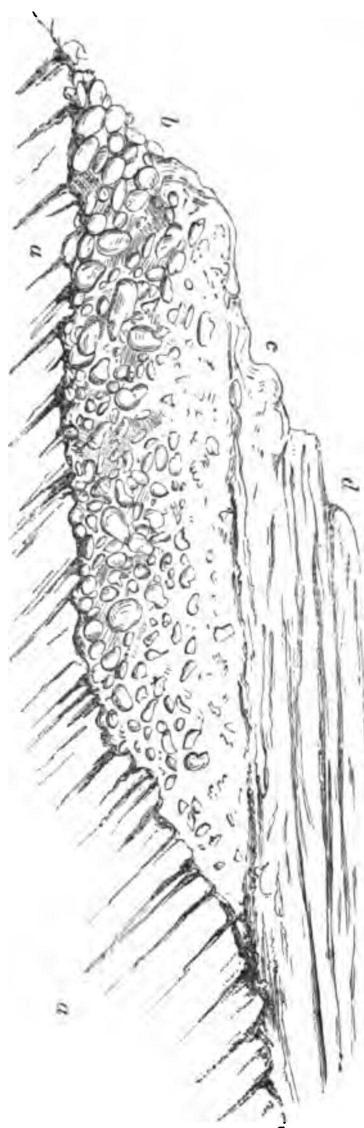


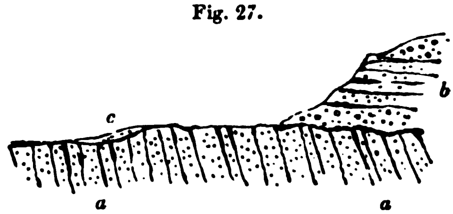
Fig. 26.

* Horizontal Sections of the Geological Survey of Great Britain, sheet 14, section 3 sheet 1, section 15; sheet 16, sections 1, 2, and 3; and sheet 17.

the matter forming the cement in the conglomerate and the various dolomitic limestones (in which carbonate of magnesia is often in very small quantities, not more than is frequently detected in common carboniferous limestones), replaces in a very slight manner the quantity of the carboniferous limestones removed.

The manner in which conglomerate and limestone rest on the edges of the coal measures at Portishead, will be seen by the accompanying section (Fig. 27), in which *a a* represent upturned and highly inclined

Fig. 27.



beds of coal measure sandstones (Pennant Grit), and *b* beds of dolomitic conglomerate and limestone in the following descending order :—1. Conglomerate; 2. Layers of red and buff-coloured sandstone; 3. Con-

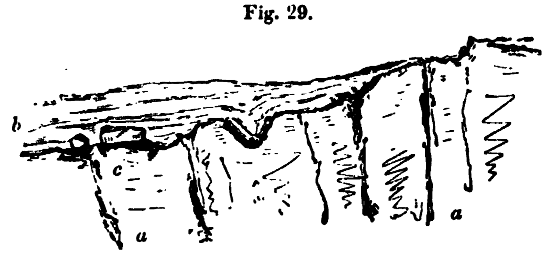
Fig. 28.

glomerate ; 4. White crystalline dolomite ; 5. Buff-coloured sandstone ; and, 6. Conglomerate reposing on the edges of the coal measure sandstones. *c* is a small patch of conglomerate, not yet removed by the breakers.

Near the landing-place at Portishead we observe the annexed good example (Fig. 28) of unconformable position, the older rock (red sandstone) having been upturned so as to be vertical, and the dolomitic conglomerate resting on horizontal beds upon its edges. Numerous examples of the varied manner in which these dolomitic conglomerates and limestones repose on the older and disturbed rocks may be seen. An accumulation reminding us of the range of a beach along a coast of the poicilitic time is well seen from the neighbourhood of Portishead, resting on old red sandstone and stretching towards Clifden; and the latter place affords a very good exhibition of the rocks under notice.

The following section (Fig. 29) illustrates a mode by no means un-

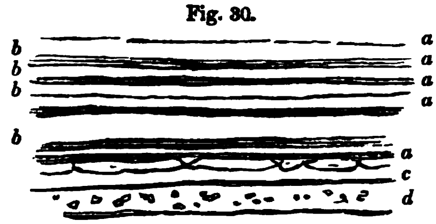
Fig. 29.



common in which the dolomitic limestone is observed to repose upon carboniferous limestone, the inequalities of the one filled up by the deposit of the other. In this section, seen in a quarry near Pen Park, north from Bristol, *a a* represent nearly vertical beds of carboniferous limestone, and *b* dolomitic limestone, *c* being blocks of the former apparently lying at the top of the carboniferous limestone, before it was so covered up.

Proceeding to the Mendip Hills, and including the carboniferous limestones isolated amid surrounding deposits of some modern date, we again observe all the varieties of accumulation previously noticed. The conglomerate, however, chiefly prevails ; at the same time in many situations we find evidences of tranquil accumulation, and an intermingling with the detrital deposits of the period, usually of fine matter, such as might readily have been held in mechanical suspension at the same time and in the same waters which held carbonate of lime and carbonate of magnesia in solution. Of this kind we may consider the alternations of red marl and dolomitic limestones observed on the descent of the hill, from the south, into Croscombe, on the south of the Mendips, and shown in the accompanying section (Fig. 30).

Fig. 80.



a a a a a, red marls; *b b b b*, flesh and buff-coloured dolomitic limestones, alternating with the marl; *c*, more nodular limestone; *d*, flesh-coloured dolomitic limestone, containing fragments of carboniferous limestone.

Upon consulting the geological maps where these dolomitic conglomerates and limestones are represented, it will be observed that carboniferous limestones are either beneath, or at no great distance from them, so that the rolled carboniferous limestone pebbles, of which they are chiefly composed, have not had far to travel. Supposing the conglomerates to have frequently been beaches, the breakers acting on the shingles would distribute them then, as we observe happens with shingle beaches now. We should expect, as the necessary change of levels relatively to sea and land took place, as they must have done under any hypothesis accounting for the accumulation of the covering rocks up to the oolites inclusive, that the shingles would be heaped up in situations fitted to receive them; as for instance, in the cove or bay that would be formed at Shipham, in the Mendip range, and in the bay between Porthbury and Westbury, near Bristol.

So much is buried beneath covering rocks that there is much difficulty (assuming these conglomerates to have been accumulations got together in the manner of beaches, or driven along in shallow water by breakers) in tracing the configuration of the land of the time. There is no difficulty, however, in seeing that considerable inequalities did exist during the whole time up to the deposit of the lias inclusive, sufficient to form numerous islands, such islands gradually decreasing in number as the land descended in this portion of the district, until even a considerable height* (about 750 feet) of the present range of the Mendip Hills was submerged at the deposit of the lias, for there appears no fault of more recent date in that rock very materially altering the relative levels of the lias and carboniferous limestone of the Mendips since that geological date.

Looking at the general position of the older rocks of the district relatively to the poicilitic or new red sandstone series, we may view this series as accumulated while a large part of Wales and portions of adjoining English counties may have been above the sea level of the time in one direction, and parts also of Devon, Cornwall and Somerset in another, open sea extending to a considerable distance eastward, covering the

* Horizontal Sections of the Geological Survey of Great Britain, sheet 17.

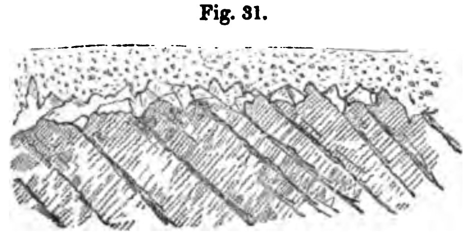
space now occupied in that direction by the accumulation of numerous sea bottoms, filled with the remains of various marine animals which in their time have ceased to exist.

Considering that the Bristol Channel may at that early geological time, as now, have been a depression covered by water, and the occurrence of the patches of the poicilitic series still adhering to the sides of the coast near Bideford, and the general character of the folds and undulations of the older rocks on both sides would appear to render this view not improbable, the Quantock Hills, the Mendip Hills, and various parts of the country in the direction of Bristol would occur as minor islands at the end of this opening, exposed to the range of waves from many directions, but most so to those from the N. E. round to the southward. A larger island would occur in the direction of Wales, and another on the south-west, forming a large part of Cornwall and Devon.

However this may have been, we have to look for the cementing matter of the dolomitic conglomerates and limestones, and this chiefly in the neighbourhood of the carboniferous limestones. As far as regards the lime and magnesia required, there would be no want of either of these substances among the carboniferous limestones, so that if water containing the needful carbonic acid, passed through their beds, joints or fissures, there would be an abundant supply for the cementing substance of the conglomerate and breccias, and for the beds of limestone when the pebbles and fragments were not present. How far there may have been springs among these rocks more charged with carbonic acid than now, rising through the cracks and fissures, consequent on the great bending and contortions which took place immediately preceding this geological period, or how far the state of the atmosphere at the time may have been favourable, or both these causes combined may have operated upon the limestones, we require a sufficient solvent for the carbonate of magnesia and carbonate of lime, and the distribution of the solution chiefly around or near the carboniferous limestones.*

* As illustrative of the manner in which water charged with carbonic acid, derived from decaying vegetation, may act on solid limestones, with interposed gravel, the following sketch (Fig. 31) of part of Milling Quarry, near Haverfordwest, may not be out of place.

Fig. 31.



When visited in 1841, the *head* or covering of gravel was being removed from a con-

From the difficulty of assigning one date only to these dolomitic conglomerates and limestones, it may be desirable to notice the poicilitic series generally as developed in Glamorganshire, Monmouthshire, Gloucestershire and Somersetshire, comprising that part of the district where they are abundant. Returning on the west to the neighbourhood of Pyle, we here find, near the church, greenish gray, gray and red sandstones, and we also observe these to be covered by red or variegated marls in the same vicinity, supporting lias. These sandstones rest on dolomitic conglomerate. We have here at least, though the thickness is comparatively inconsiderable, evidence of four conditions. First, that during which the pebbles and fragments of the conglomerate were accumulated; secondly, the introduction of the necessary cement, joining them together; thirdly, the drifting or accumulation of sands, partly coloured by peroxide of iron; and fourthly, a deposit of marls. As far as regards the formation and accumulation of the detrital parts of these beds, there was a change in the forces required, sufficient for the production of gravels, to the quiet descent of fine matter in mechanical suspension. Proceeding towards Bridgend the same facts are observable, and between the two places there is an interesting example of a sandstone of this series, assuming the character of a quartz rock, the grains being chiefly of white quartz firmly bound together by nearly colourless silica. Blocks of this rock are observed crossing the western part of Newton Down. On the coast between Dunraven Castle and the mouth of the Ogmore we see dolomitic conglomerate resting on carboniferous limestone and covered by lias, so that if intermediate sands and marls have once existed, they were removed by denudation prior to the production of the lias.

Hence westward there is much intermixture of red marls with the dolomitic conglomerates and limestones, when the former are found, and but little sandstone is seen. It should, however, be observed that on part of Coity Hill we have a recurrence of the quartz rock bed previously noticed. Towards Pendoylon and Cardiff, we have a more marked accumulation of sandstones and marls, the former comparatively rare, above the dolomitic limestones and conglomerates, and beneath the lias of that part of the country. At Penarth Cliff, near Cardiff, we find the following section.

siderable portion of the quarry to enable the workmen to proceed. The asperities on the surface of the upturned beds were so full of jagged ridges and depressions as closely to resemble some models of the Higher Alps. It was evident that these inequalities were produced by the percolation of the water, containing carbonic acid, through the superincumbent gravel; the waters in the cavities holding bicarbonate of lime in solution. Any motion of the gravel would have been sufficient to grind down all the fine edges and peaks of the asperities. We often appear to have a similar cause for the ridges, furrows and funnel-shaped holes observed on the surface of the chalk.

	Ft.	In.
1. Lias limestones and shales alternating		
2. Blackish marls, sometimes containing iron pyrites	12	0
3. Greenish gray marls, with a few purple-coloured bands. Beds irregularly indurated	30	0
4. Band of gypsum in places . . . . maximum thickness	1	6
5. Variegated red and greenish blue marls	20	6
6. Two courses of gypsum nodules, united by strings of fibrous gypsum, in variegated marls	2	8
7. Two beds of greenish blue marl, with a seam between of red marl, 2 inches thick	1	4
8. Red marls, with some stripes of greenish blue. Contain occasional vertical stripes of gypsum	10	0*

From Penarth Point for 17½ miles towards the north-east, whatever members of the poicilitic series may be beneath, they are covered over by the alluvial deposits of the coast. From Undy to Mathern, we observe red marls with some red sandstones, and these rest upon carboniferous limestone, with the exception of a small patch or two of intervening dolomitic conglomerate and limestone. On both sides of Aust, or Old Passage, a good section of the series is observable, based on previously disturbed carboniferous limestone and surmounted by lias, so that its whole thickness, as there developed, is exposed. The following is a section, much broken by small faults,† as measured on the Aust side in company with Mr. William Sanders.

		Ft.	In.
Lias.	1. Gray argillaceous limestone with shale partings; the bed, named Cotham Stone, among them; *Ostrea* (small), *Plagiostoma gigantea*, *P. striata*, *Modiola* (small), *species of Echinites*, *Bones*	2	6
	2. Gray marly clays	3	0
	3. Seam of limestone.		
	4. Gray marls	7	0
	5. Argillaceous limestone	1	0
	6. Gray marls	2	6
	7. Gray marls, with three beds of nodular limestone . .	3	0
	8. Gray marls	3	0
	9. Gray marls, with selenite	5	0
	10. Argillaceous limestone; *Fish scales*, *Elytra of Insects*, *Modiola*, *Terebratula*, &c.	0	8
	11. Black shales	6	0
	12. Gray argillaceous limestone beds, with *fish scales* . . .	0	8
	13. Black laminated shale	3	0
	14. Thin calcareous and arenaceous bed, containing *Saurian remains* and *Fish scales*	0	2
	15. Black laminated shale	0	8
	16. Bone bed; commonly a conglomerate, composed of rounded portions of an argillo-arenaceous and calcareous rock, mingled with *Saurian* and *Fish remains*, *Coprolites*	0	1 to 8

* It is not improbable that this section may be based on some red sandstone.

† For a section of Aust Cliff, see Buckland and Conybeare's Observations on the South-Western Coal District of England, Geol. Transactions, Second Series, vol. i. pl. 37.

New Red Sandstone Series.		Ft.	In.
	17. Pale arenaceous marls, with nodules of sandstone; calcareous cement; generally changes to an arenaceous marlstone	1	0
	18. Greenish marls, with small nodular fracture, varying in the lower part to sandy shales	2	0
	19. Marly sandstone; partly calcareous cement	0	6
	20. Arenaceous marlstone, nodular, greenish gray and blue	6	0
	21. Red marls, with stripes, and nodules of greenish blue	15	0
	22. Red marls	50	0
	23. Gypsiferous beds; gypsum in beds and strings	26	0
	24. Red marls, somewhat sandy at the base, where they rest upon upturned carboniferous limestone	21	0

In the country inland, from Aust Cliff by Olebury towards Berkeley on the northward, and by Compton Greenfield towards the banks of the Avon on the south, the same general kind of section as that observable at the Old Passage is to be found upon the irregular border of the poicilitic series which extends along the line of the older rocks, covering over the dolomitic limestones and conglomerates. In some localities red sandstones are more prevalent at the lower part than in others, yet, as a whole, red marls are the most characteristic deposits, the upper portions striped by green or bluish bands, showing different states of the iron by which the whole is coloured. The following analysis of the red and blue marls from Aust Cliff, made at the laboratory of the Museum of Economic Geology, by Messrs. Ransome and Cooper, will illustrate the different states of the iron in them.

	Blue Marl.		Red Marl.	
	I.	II.	I.	II.
Silica	48·62	48·99	48·69	48·10
Protoxide of iron	13·09	12·57	4·79	4·44
Peroxide of iron	..	..	9·09	9·07
Alumina	9·01	9·03	8·77	10·00
Lime	8·39	8·10	8·68	8·71
Magnesia	1·00	0·98	0·94	0·91
Soda	0·58	0·40	0·53	0·42
Potash	3·30	3·73	3·15	3·35
Phosphoric acid	*trace*	*trace*	*trace*	*trace*
Sulphuric acid	0·14	0·18	0·27	0·24
Chlorine	*trace*	*trace*	*trace*	*trace*
Carbonic acid	10·18	10·08	8·56	8·72
Organic matter	1·90	1·82	1·18	1·12
Water and loss	3·79	4·12	4·25	4·92
	100·	100·	100·	100·

Metallic Iron contained in these Marls.

	I.	II.	Mean.
Blue marl	10·11	9·71	9·91
Red marl	10·60	10·34	10·47

These analyses show that the marls are essentially of the same composition, and that the difference of colour is due, as in the marls of the

old red sandstone (p. 55), to the different states of the iron contained in them, the change from the original peroxide to the protoxide having been produced by the action of the contained organic matter in a state of decay. Dr. Playfair, under whose inspection the analyses were performed, remarks that the carbonic acid is greater in the blue marl, because the carbonic acid from decaying organic matter has united with the protoxide of iron to form the carbonate.

By reference to the maps it will be seen that the new red sandstone series is represented, when not overlapped by lias and other members of the oolitic series, or by alluvial accumulations, as skirting the older rocks which rise to the surface in the Tortworth, Bristol and Mendip Hill districts. Throughout that area the accumulations present a very common general character. As has been stated, the conglomerates and limestones may have been formed at different times, similar causes having produced similar effects during the period occupied by the formation of the whole poicilitic series. The red sandstones are unequally distributed. Near Bristol some are found, and extend thence along the skirts of the coal field towards Cromhall. There is a section of some beds of them in the new cut at Bristol. Red sandstones are seen in several places from Wrington easterly towards Chelwood and Farington. Where observed they usually constitute the base of the marls, though occasionally we appear to see an ancient shingle beach (dolomitic conglomerate), a sandy bottom (red sandstones) seaward, and muddy deposits (red marls) still further out.

Marls are very commonly associated with the dolomitic conglomerates of the Mendip Hills, and cover them up. Though the following section extends up to the inferior oolite inclusive, it may be useful in showing the manner in which the poicilitic rocks rest on the carboniferous limestone between the Mendip Hills and the Bristol District.

General Section observed between Dundry and Winford.

		Ft.	In.
Inferior Oolite.	1. Yellowish limestone: upper beds rather crystalline; lowest beds containing ferruginous oolitic grains, and very fossiliferous	30	0
	2. Gray marls	30	0
	3. Yellow sandy limestones	15	0
	4. Sandy marls	10	0
Lias.	5. Gray marls	20	0
	6. Dark-coloured marls, with nodules of argillaceous limestone	280	0
	7. Beds of argillaceous limestone and marls alternating	120	0
	8. Black shales (bone beds not apparent)	10	0
New Red Sandstone Series.	9. Blue and bluish green marls	5	0
	10. Red marls	50	0
	11. Band of yellow dolomitic limestone	4	0
	12. Red marls	20	0
	13. Dolomitic conglomerate (variable).		
	14. Carboniferous limestone.		

Quitting the Mendip Hills and proceeding to the S. W., we find a large surface exposure of the poicilitic series. The nearest good section is exposed on the coast close to Watchet, where we observe gypsum, in tolerable quantity, in about the same relative position as at Penarth, on the opposite side of the Bristol Channel and at Aust Cliff, being, however, more abundant than at either of those localities.* The Quantock Hills rise as an island out of the new red sandstone series surrounding them, and tracing this series of accumulations hence against the edge of the Devonian rocks and coal measures to Tor Bay, we are soon struck by its adaptation to a variety of sinuosities resembling the outline of a coast, to which the lines of the various contortions and rolls of the older rocks had given a general character. No doubt denudation has removed much which once covered these older rocks, as is shown by such an outlying patch as that at Hatherleigh, and faults of more recent date than the deposit of the poicilitic series may give lines of juxtaposition ranging in particular directions, such as that large dislocation which runs from near Broad Clist by Newton St. Cyres to the westward; but, with due allowances for these circumstances, the general arrangement of the line in the manner of an ancient coast is still striking, more particularly when we regard such gulfs as are seen at Porlock and Luckam.

From the Bristol Channel, near Minehead and Washford, passing down the strait of the new red sandstone series which separates the Quantock Hills from the Devonian rocks on the west, and thence by Wiveliscombe, Milverton, and Runnington to Thorn St. Margaret on the south, there is a very interesting conglomerate (usually containing limestone pebbles in considerable abundance, and often cemented by a mixture of the carbonates of lime and magnesia), more particularly when viewed in connexion with the dolomitic conglomerates above mentioned. Commonly this conglomerate is separated from the older rocks by red or claret-coloured sandstones and marls, chiefly the former, and the limestone pebbles and the cement are sufficiently abundant to permit the rock being burnt for lime, when any pebbles of sandstone or other siliceous rocks are removed. At Wiveliscombe the sections are favourable, and a thickness of from 140 to 180 feet of red sandstone is seen to separate this conglomerate from the older rocks adjoining and subjacent.†

Although the conglomerate may readily have extended from the high land in the west (Main Down) and the part connecting it in that direction with Castle Hill, on the east, have been removed by denudation, this, and other sections, are sufficient to show that in this part of the general

* For a sketch of the manner in which the gypsum occurs at Watchet, see Geological Report, &c., p. 196, fig. 24.

† Geological Report, &c., p. 198, fig. 25.

district the conglomerate was preceded by a deposit of sand. We have to account for the limestone pebbles, and for the dolomitic cement (the carbonate of magnesia being, however, in very variable quantities, and frequently even disappearing entirely), after some arenaceous accumulations had been effected. We have not to consider them, therefore, as derived from fragments of the adjacent land at the commencement of the conditions under which the new red sandstone series was deposited. The pebbles are such as may have been derived from abraded carboniferous limestone. Though limestones do occur in the Devonian rocks adjacent, both in the Quantock Hills, and in the range between Tolland and Withycombe, they do so in very subordinate quantity, and mingled with other beds which could readily furnish some hard materials for a conglomerate. The rocks supplying the fragments for these pebbles may have existed towards the north or north-west. In the latter direction we find the carboniferous limestone of the Mendip Hills, with abundant patches of a generally similar conglomerate; and in the former the same limestone rocks, and a partial covering of conglomerates. We observe, also, that the conglomerates do not extend further south than Thorn St. Margaret, where they fine out, and disappear. There is reason to suppose that both towards Glamorganshire, across the Bristol Channel, and towards the Mendip Hills, there may have been much carboniferous limestone; and there appears no geological difficulty in considering that the conglomerates of West Somerset may have been, in a great measure, formed from their destruction, the portions which resisted the denuding causes of this and subsequent geological times being now concealed beneath their covering of more modern accumulations.

The drift of these pebbles, becoming mingled with others derived from fragments of different rocks in their progress, by any prevalent breakers of the time along coasts, and over hard shoal ground, would accord with that which frequently happens at the present day, and the cementing matter would only be the extension of that which joined so much gravel together, and even formed solid beds by itself, at a moderate distance. We could scarcely suppose that the calcareous or dolomitic matter should not be diffused, to a certain extent, in the waters which held it in solution, carried by the tidal, or other currents of the time. That it was so carried appears proved by the dolomitic limestone occurring in a concretionary manner, and in lines, at Peppercombe, on the west of Bideford, in the patch of the red conglomerate, sandstones, and marls, which there reposes upon the coal measures, a portion rising above the sea, or escaped from denudation, and showing the extension of the poicilitic series in that direction. The pebbles of the conglomerate at Peppercombe are derived from the adjacent older rocks, from the abrasion of which they were furnished, but the dolomitic matter appears like the continuation of a solution borne

to the beach or sea bottom of the time and locality, and mingled with it. Such a conclusion would accord with other calcareous deposits, solutions of the needful matter covering areas of variable dimensions, and mingling with, or solely constituting, the accumulations forming in them.

Continuing a course still more southerly, we find the lower part of the new red sandstone series so associated with fused rocks that there is reason to conclude that the igneous action, the first effects of which in Cornwall and South Devon were observable among the Devonian rocks, was still in force in this part of the district after the great contortions and disturbances experienced by the older deposits. We further see that the products then ejected, more partake of the chemical character of the granitic, than of the trappean rocks, as if this igneous action was connected with that from which the granites of Devon and Cornwall were produced. The igneous rocks associated with the new red sandstone series vary from porphyries, the base of which is chiefly felspathic, with large crystals of glassy felspar, to different rocks exhibiting the effects of conditions unfavourable to crystallization, many of them being vesicular.

In a kind of gulf of poicilitic rocks, extending from the vicinity of Tiverton into the coal measures near Calverleigh, we find the vesicular varieties, sometimes porphyritic, and the more compact kinds so associated with the red conglomerates as to show that a gravel was first formed of portions of the adjacent beds, upon which fused rocks were poured out, a kind of arenaceous product being so mingled with the ordinary red sandstone as to lead to the supposition that ashes may have been here thrown out, as from a volcanic vent, and became mixed with the ordinary sand then depositing. A conglomerate surmounting the igneous rocks contains fragments of them, mingled with those of the sandstones and shales on which the whole rests.*

The country near Silverton, Thorverton, Kellerton, and Crediton, affords other examples of these igneous rocks, associated with the lowest members of the poicilitic series, as there developed, and the vicinity of Exeter also presents interesting instances of the like kind.† As we have had elsewhere occasion to remark,‡ the igneous rocks on the S. W. and W. N. W. of Crediton often descend downwards in hard masses, as if filling up craters or cracks through which they rose, while more vesicular varieties extend laterally, the same chemical compound having assumed a different mineral aspect, according to the conditions to which it has been subjected, a pipe or fissure affording a more compact rock upon cooling than the thin and nearly horizontal streams of melted

* Geological Report, &c., p. 199, fig. 26.

† For more detailed notices of these rocks, see Geological Report, &c., p. 199–204.

‡ Ibid., p. 201.

matter. The high road out of Exeter to Moreton Hamstead, over Pocombe Hill, affords a good section of one of the igneous masses of this kind, which has overflowed the edges of the carbonaceous slates. A short distance further south a long line of igneous rocks is perceived at the base of the new red sandstone series, and they may be observed resting on the edges of the subjacent carbonaceous rocks, between Ide and Dunchidcock. Near Ideston and Western Town, they appear intimately associated with the red conglomerates.

Judging from the abundance of pebbles and boulders of similar igneous rocks contained in the red conglomerates, extending from Exeter to Teignmouth, many masses of such rocks must have suffered great destruction,* more particularly when we consider the amount of such fragments which must be concealed from our view by superincumbent and later-formed beds of red sand and gravel.

It would appear probable that we may regard the porphyry, the base of which is a somewhat earthy compound of felspar and quartz, containing crystals of mica and (more rarely) felspar, and which is seen to break through the older sedimentary deposits at Cawsand, near Plymouth,† as of the same geological date with the igneous rocks above mentioned. Under this view it would be connected in age with the patch of new red conglomerate near Thurlestone, in Bigbury Bay,‡ and with that at Slapton, in Start Bay, both which show the continuation of the new red sandstone series round this southern part of Devon. How much more of this series may be beneath the sea, extending on the south-westward towards Cornwall, it is impossible to judge, but these patches, with that on the north of Devon, point to a more prolonged fringe of such accumulations than the mode of occurrence of the poicilitic rocks, extending on the east from Tor Bay to Watchet and Porlock, would lead us to suspect.

The igneous rocks above mentioned may probably be regarded as the products of the last exertion of those forces which threw up the granites and elvans of this district, and such rocks may be far more extended eastward than we can trace them, more modern accumulations covering them up, and concealing them in that direction. The matter ejected may be considered more as a modification of the granites and elvans than any new upburst of the hornblendic rocks which first appeared, as if the upthrust of the matter of the granites had entirely altered the conditions for throwing out the igneous products at first so abundantly formed. These rocks may be connected in date with some of the elvans,

* A very common variety in this range of beds consists of a porphyry with a felspathic base, through which crystals of both quartz and felspar are distributed. A portion still remaining in place of a similar rock is to be seen above Ideston and Knole. There are, however, many varieties of which no mass is visible.

† Geological Report, &c., p. 212, fig. 30; and p. 279, fig. 33.

‡ Ibid., p. 211, fig. 29.

since many cracks, or fissures, westward may have had granitic matter injected into them, while a modification of the same matter was thrown out in fusion, and mingled with the detrital accumulations of the period on the eastward. Of any such contemporaneous action we have, however, no good proof.

Considered without reference to these igneous products, or the fragments of them contained in the conglomerates, a large portion of the lower beds of the poicilitic series, from the Bristol Channel to Tor Bay, was chiefly formed of a gravel, composed of fragments of the older and adjacent rocks, frequently rounded, though usually showing no very distant removal from the parent beds, so that where limestones abound, as is the case in the Tor Bay, Babbacombe Bay, and King's Kerswell district, fragments and pebbles of limestone are common in the adjoining conglomerates. These conglomerates can be well studied on the coast from Babbacombe Bay to Teignmouth. Thence to the embouchures of the Exe and the Otter they pass with much alternation and intermixture into red sandstones, which, in their turn, graduate further westward into red marls, also by alternations and intermixtures, from Sidmouth to Seaton and Axmouth. From the latter place to the first rise of the poicilitic series from beneath the lias on the east, there is much interstratification with variegated beds.

Collectively, with every allowance for a fallacious depth, caused by the irregular drift of gravels and sands, the section of the new red sandstone series, presented by the south coast of Devonshire, is of great thickness. The coast, no doubt, gives too great a depth for the lower conglomerates, as they rest against an interior range of the older rocks, somewhat parallel to the sea line, from Babbacombe to the neighbourhood of Teignmouth. If, however, to avoid the error thence arising, we take a straight line inland, from Poltimore, where a headland of carbonaceous rocks enters the great horizontal exposure of the poicilitic series, to the capping of that series by the lias, near Axminster, and assume a horizontal plane, and a dip of only 1° (one sufficient, after allowing for faults and curvatures of beds), we obtain the depth of 1850 feet for the South Devonian development of the new red sandstone series.

We can readily trace the three great divisions into which this thickness may be separated, namely, a base of conglomerates, a central portion of sandstones, and a covering of marls, through the country northward, to the sections exposed on the Bristol Channel. Though much of it is overspread by an extension of the upper green sand, forming the highest part of the Black Down Hills, and their continuation to the coast, from the vicinity of Sidmouth to Lyme Regis, sections across the country, from the lias on the S. E. of Taunton to the Devonian rocks near Wiveliscombe, lead us to consider that the general thickness found in

South Devon is materially diminished towards the north. If we take the same angle of dip (1°) as was done for South Devon, and estimate the thickness between the limestone of the carbonaceous series at Whipcots to the lias near Angersleigh, it would amount to 740 feet. Between the lias of Stoke St. Mary, near Taunton and the Quantock Hills on the north, the total depth is probably not much beyond 280 feet.

Quitting this southern country, and passing to the northward of the Silurian rocks and old red sandstone, forming the shores of the Severn at Purton Passage, we find the new red sandstone series, resting upon the old red sandstone and Silurian rocks of Dean Forest, and of Huntley and May Hills. The upper member of the series, that is, the red and variegated marl is seen to rest on the disturbed older rocks, as in the country more southward, and the general thickness is comparatively inconsiderable, probably near Newnham not exceeding 250 feet. The following is a section taken across the country from Golden or Garden Cliff, Westbury-on-Severn, towards Dean Forest, the upper portion, including the base of the lias, well exposed at Golden Cliff.*

Section of the lower part of the Lias and of the upper part of the New Red Sandstone near Westbury-on-Severn.

		Ft.	In.
Lias.	1. Thin bed of argillaceous limestone	0	4
	2. Argillaceous shale	2	0
	3. Thin bed of argillaceous limestone, full of the shells of young *Aviculæ*	0	4
	4. Gray brown shales, containing a bed of iron pyrites 4 feet from the top	6	0
	5. Irregular bed of limestone	0	5
	6. Dark shales, abounding with small crystals of selenite; iron pyrites in irregular bands (*fossiliferous*)	14	0
	7. Sandstone, commonly micaceous; often irregularly marked in plates (with occasional argillaceous partings) of one set of current or ripple marks above each other. Exhibits a variety of markings, like the bottom of a sandy and shallow sea. Full of *fish teeth* and *scales*, with occasional patches of *coprolites*, distributed as at the bottom of a sea	0	9
	8. Dark shales, with iron pyrites; contain *bones of Saurians*, *fish teeth*, &c.	1	6
	9. Band of sandstone; *fish teeth* occasionally seen in it	0	4
	10. Dark shales, with patches of iron pyrites, mingled with *Saurian bones and teeth*, *fish bones*, *scales*, *and teeth*, *Coprolites*, &c.	1	0
	11. Rubbly blue marl	12	0
	12. Alternating blue and red marls, the former predominating upwards	30	0
	13. Red marls	180	0
	14. Gray arenaceous beds, argillaceous shales, and blue argillo-arenaceous beds (*fossiliferous*)	15	0
	15. Red marls, with an occasional band of sandstone	120	0

At Newnham the cliff affords a section of certain beds among the red

* So termed from the bright golden appearance of the iron pyrites found in the lias.

marls which can be traced, with some intermediate breaks, for a considerable distance northward, occasionally containing organic remains, fish teeth, palates, and defensive fin bones, with bivalve shells, and marking a state of things, for a time, favourable to the existence of animal life, amid a series of deposits not so characterised. These beds most frequently consist, though often modified, of gray sandstones and shales, with traces of calcareous matter. The maps of the Survey will show the course of these beds northward, a separate colour having been assigned to them, and the complicated form they assume will present a view of the minor undulations of the upper part of the new red sandstone series, such undulations being also cut by those of the present surface of the ground.

Proceeding northward from the vicinity of Newnham, and following the line of junction between the subjacent older rocks and the poicilitic series, the marls, or upper part of that series, are found to overlap the lower portions, and repose upon old red sandstone to the vicinity of Flaxley, where they rest upon the Silurian rocks of the Huntley and May Hill range. About a mile southward from Huntley Church, red sandstones emerge from beneath the marls, by which they were covered up on the south. These sandstones are afterwards observed to cover the Silurian rocks of May Hill towards the north, supporting the continuation of the red marls, which southerly rested upon the older rocks. Near Newent (including Bowlsdon) these sandstones become intermingled with conglomerates, composed of pebbles of the older rocks, either resting upon old red sandstone or coal measures, and this intermixture of red conglomerates and sandstones is continued, reposing upon old red sandstone, to the southern part of the Malvern Hills which extends from Haffield to Keys End Hill.

A glance at the maps shows these conglomerates and sandstones, the latter prevailing towards the base of the mass, to be confined to a kind of bay, backed by the lower beds of the old red sandstone (comparatively easy of removal by breakers from the abundance of marl in them), with two points of harder substances composed of the igneous rocks of Keys End Hill on the north, and the limestones and harder beds of the upper Silurian rocks of part of the May Hill district on the south. This bay forms a kind of indentation, in which we might expect such conglomerates as we find to have been easily accumulated by the breakers rolling in from an open sea on the east, and which fell with less accumulating power of this kind upon the deeper coast of the Malvern range, as now happens on many coasts of similar differences in mineral character. On the south, however, we should have to consider that this mass of shingle and sand tailed round part of the May Hill country, not falling into deeper water for some distance in

that direction. Looking to such natural causes as are now in operation, we can readily understand that a contemporaneous deposit, ranging along any coast presenting variable conditions for its accumulation and general character, should be higher, as regards horizontal level, in one part than in another. We should expect at the bottom of a bay, backed by soft rocks, easily abraded, that shingles and sand would be raised above the level of the accumulations at the points or exposed lines of deep-water coasts. If, therefore, a general depression of land, as regards the sea level, continued, and a body of red mud, now marls, covered up such accumulations unequally, we should anticipate that future denudations would expose these subjacent shingle and sand beds, according to the relative height of the latter above the other deposits of their period. And this would appear, judging from present equal levels, to have been the case in this district. A case of a beach accumulation of the date of the lower deposits of this series would appear to occur, in a good natural position, at the north end of this bay, between the point of Keys End Hill and Haffield.

Shortly after passing the point of Keys End Hill, northward, we find the sandstones and conglomerates again covered over by the marls, and the peculiar and marked beds containing organic remains, closely approaching to Ragstone and Midsummer Hills, of the Malvern range, so that there is an overlap upon the lower members of the poicilitic series, similar to that observable southward near Newnham. A minor patch of sandstone occurs indeed at Little Malvern, and this may readily have been part of a beach heaped up higher than the general level of the new red sandstone accumulations, anterior to the deposit of the marls, upon general denudation appearing above them on the eastern flanks of the Malvern Hills.

The mode of occurrence of the new red sandstone series, eastward of the range of older rocks, from the vicinity of Pyrton Passage to the Malvern Hills is highly instructive, and we can scarcely avoid believing that we see a line of ancient coast, formerly bounded by the seas of which the waters so commonly, for a time, held peroxide of iron in mechanical suspension, the action of the tides and breakers being such as we now find them on like coasts, and producing similar results, according to conditions. As geological time rolled on, this portion of our district was marked by the accumulation of mud, overspreading the previous deposits of the period, so that, as the land descended beneath the level of the seas, this mud overspread all within its reach, covering over the inequalities of the series of which it forms a part, as well as the still older rocks supporting the whole. It would be premature even to sketch the mode of occurrence of the poicilitic series more northerly. A view of its probable origin and mode of accumulation in that direc-

tion should embrace an area far more extensive than that included in our district, and the connexion and modification of its various parts could only be properly understood by comprising accumulations not yet examined by the survey.

Taken as a whole, a large amount of peroxide of iron was included among the accumulations of the new red sandstone or poicilitic series, as well in the cement of its conglomerates, and of its sandstones, as disseminated among its marls. In some places it is so abundant as to be worked as hematite ore, and the same ore is often found in small veins amid the red sandstones, more especially in Southern Devon. The hematite of the neighbourhood of Porlock and Luckham is found in patches, constituting as much a portion of the beds as the associated conglomerates and sandstones, and is extensively raised, where sufficiently rich, and sent to the iron works of South Wales and Monmouthshire. Strings also of rich dark-coloured hematite run among the conglomerates and sandstones of Luckham. This abundance of hematite iron ore in the lower part of the series is not confined to Luckham and its vicinity, but is observed also at St. George's in Gordano, near Bristol, where it has also been worked. We observed hematite, though not in sufficient abundance to be profitably raised, at the base of the series, beneath dolomitic conglomerate, near Llanharan, in Glamorganshire, so that the area is considerable over which peroxide of iron was thrown down in such large proportions to the detrital substances with which it was associated.

Throughout the whole deposit, the peroxide of iron was in sufficient quantity to tint the various detrital accumulations red, with the exception of the upper beds of marl, adjoining their covering of lias, where bands of bluish green or blue are interstratified with the red, and in which the iron is, as has been seen (p. 254), in the state of a protoxide. It even colours the cement of the dolomitic conglomerates and of the limestones to a great extent, more, however, in some localities than in others. As in the case of the old red sandstone there is much difficulty, in the present state of our knowledge, with respect to the origin of this quantity of peroxide of iron, for not only does it characterise the accumulations of this date in the British Islands, but also those contemporaneously formed over many parts of Europe, so that wide-spread and, probably, long-continued similar physical conditions, as regards the supply and dissemination of the iron, seem required. We have, therefore, to consider any portion of this series occurring in our district as but a part of a great accumulation in which peroxide of iron was intermixed to such an extent as to give it a prevalent colour.

Confining ourselves to South Wales and South-Western England there is little difficulty in seeing that the pebbles and fragments of the

conglomerates are to a great extent local, not so far drifted as the pebbles of a large proportion of the superficial gravels of England. The effects of atmospheric influences and the action of running waters inland, and of breakers on coasts, or shoals would suffice to produce the pebbles and fragments in the conglomerates, and that such causes existed upon the dry land of the time and around its shores, in the direction of Wales and the adjoining English counties, in one direction, and of Gloucestershire, Somerset, Devon and Cornwall, in another, appears probable. Such an area as Wales, with a large proportion of the counties of Monmouth, Hereford and Shropshire, would then have furnished an abundance of river-borne detritus, as it now does after the lapse of that great amount of geological time which has intervened between that period and the present, and during which so many conditions for the abrasion of the higher lands of that time have been in full force. The same may probably also be said with Devon and Cornwall, joined or nearly so, at first and by low ground, with the higher lands of Wales and neighbouring districts to the north, this low land becoming covered by the poicilitic accumulations as geological time advanced, and the levels of sea and land changed, so that the land descended beneath the level of the sea. That such change of level did occur, is abundantly proved by the manner in which one deposit after another covered up the older rocks, as is so well shown in the Mendip Hills.

The island character of this land would be favourable to abrasion and the distribution of detritus by breakers and tidal currents. In estimating its extension westwards we should bear in mind that the Irish Channel is but a shallow depression, and that if between the coast of Wales and that of the opposite part of Ireland, St. Paul's Cathedral of London were placed in the common deep situations, the top of the building would rise to about the surface of the water. So that allowing for denudation acting through a long lapse of geological time, and for depression ultimately more on the west than on the east, a large part of Ireland may readily have been joined to Wales at this period. Judging from the kind of accumulations observed on the east, we should expect that there had been more open sea in that direction, throwing breakers against the eastern coast from the land now forming Tor Bay to the eastern parts of Denbighshire and Flintshire, in North Wales. As we can scarcely consider that the forces which crumpled and contorted the older rocks in this part of the world, prior to the new red sandstone accumulations, should be succeeded by perfect tranquillity at the commencement, at least, of such deposits and that there should not have been minor movements during the adjustment of the masses so contorted and crumpled, after the great pressure required had forced the older rocks into those complicated folds we now observe, we may

readily imagine that waves would frequently be produced similar to those witnessed during great earthquakes. If we had a coast of the kind supposed, and the geological evidence is such as to render it by no means improbable that there has been such a coast, the aid of the additional and larger breakers, thus added to the common breakers arising from winds, would most materially assist, not only in abrading the coast, but also in distributing the heavier detritus, such as pebbles. Such waves would tend to stir up the bottom at greater depths than those arising from ordinary causes; thus separating the finer sedimentary matter, such as sand and mud, and keeping it mechanically suspended, while the heavier parts, such as pebbles, were brought closer in juxtaposition, and more continuous gravel beds produced than would be otherwise formed. From the deposits of the sand and mud, when the motion necessary to keep them in mechanical suspension ceased, many a sand and mud layer might have been introduced amid the general accumulation of gravel beds.

Be this as it may, there is a very marked difference of the deposits in the ascending order, and the common action of causes for the production and distribution of sand and mud, with the exception of the peroxide of iron disseminated through them, would appear ample for the accumulations then formed. Among the sandstones in some localities diagonal partings are not uncommon, showing the propulsion of sand along the bottom by the friction of the water above, which has occasionally left those inequalities, commonly known as ripple marks. Gravels also are sometimes introduced among the sands, and there is the same order of unequal drift by water along the bottom, noticed in the case of the old red sandstone.

As the land subsided, the comparatively low portion joining Wales with Devon and Cornwall seems to have been gradually submerged, so that sands were drifted over part of it. It does not, however, appear that deposits were effected to any great extent until the period when the red marls prevailed, when the waters of the time evidently overspread a considerable portion, there being a free passage of sea between Wales and Devon, with outstanding islands. The kind of deposits then effected points to much tranquillity, though along the shores many a beach seems to have fringed the lands, becoming covered up in its turn as the land still continued to be depressed relatively to the sea level. Along the shores of the limestone districts and islands, the beaches appear to have been bound together, as beaches in some parts of the world now are, by calcareous or dolomitic matter—this matter also spreading out to sea, so as to form limestone or dolomitic beds amid gravels, sands, or mud, in adjoining sea bottoms.

At a particular time during the accumulation of the marls, sulphate

of lime in solution must have been disseminated over a wide area, becoming intermingled with the marls in such a way that strings and nodules of gypsum were produced. This deposit of sulphate of lime may be traced from near Branscombe, on the southern coast of Devonshire, to Watchet, and to Penarth, on the north coast of the Bristol Channel. It is again found at Aust Cliff, and may be observed in the marls of the new red sandstone, thence extending northward up the great Vale of the Severn. As is well known, the same mineral substance, and in a similar geological position, is observed still more northward. The causes, therefore, for the solution, dispersion, and deposit were common to a wide-spread area of the same period. In the neighbourhood of Bristol sulphate of strontia to a certain extent replaces the sulphate of lime, and large quantities of it are found in the direction of Yate.

Though arenaceous matter is sometimes disseminated among the marls so as even to constitute sandstone beds, the structure of the main mass points to much quiet deposit, and the substances thrown down are such as could readily be held in chemical solution or mechanical suspension, and as could easily have travelled long distances with a slight movement of water. Amid them, on the north of the old straits between Devon and Wales, we find that there was at one time a space from which the usual abundance of peroxide of iron was absent, and that fish lived and died in it, and perhaps saurians may eventually be found to have done the same. The area thus circumstanced was even in our district, not small, being at least 110 square miles; and it may be regarded as only a portion of a still larger area of the same kind extending more to the northward. It seems to have been a kind of first and imperfect development of those conditions which afterwards prevailed at the period of the lower lias, or of the upper part of the new red sandstone series, as geologists may find it convenient to divide the beds at the base of the lias developed at Aust Cliff, Golden Cliff (Westbury-on-Severn), and other places.

Finally, a very common character became prevalent over the whole area in which the marls are found, reminding us of the alternation of blue or bluish-green beds observed in the old red sandstone; and it appears more probable that the red colour was discharged by the action of decomposing vegetable matter, the peroxide to a great amount reduced to a protoxide of iron, than to suppose multiplied changes of water, sometimes replete with peroxide of iron, at others free from it. It is found that these blue or bluish-green marls contain carbonaceous matter, like those of the old red sandstone; and near Lyme Regis plants are found in these upper beds.* Much carbonaceous matter

* With fish scales near Culverhole Point and Charlton Bay.—Geological Report, &c., p. 219.

enters also into the composition of the black or dark-coloured shales covering the variegated beds; so that this substance was not wanting in the accumulations of the time. The upper beds frequently, also, show that calcareous matter was then held in solution by the waters in which they were formed, the commencement, as it were, of that abundance of it which entered into the composition of the lias limestones surmounting the variegated marls.

We may regard the whole deposit of the new red sandstone or poicilitic series as filling up great inequalities in the older rocks, thrown by crumpling, contortion, and faults into a very uneven state, partly above the level of the sea, partly beneath it. There is evidence in our district of changes in the relative level of sea and land, so that these older rocks were gradually depressed to a great extent beneath that level; and as this happened the deposits, as a whole, became such as would require greater tranquillity for their accumulation and repose. How far this final state may be due to considerably increased depth of water, or to shelter from disturbing causes, does not clearly appear. As far as regards exposure to the east, there is no evidence of more shelter at the close of the new red sandstone series than at its commencement. For the reasons before assigned (p. 51), we should expect few marine animals to have lived upon or in sea bottoms so impregnated with peroxide of iron, though some plants or animals drifted from the adjoining lands might have left their remains entombed in the accumulations of the period. In the limestones and conglomerates there would be some chance of discovering organic remains; and it is possible some marine shells may eventually be discovered in them, as they are in the magnesian or dolomitic limestone ranging from Nottinghamshire to Durham and Northumberland. In the dolomitic or magnesian conglomerate of Redland, near Bristol, Dr. Riley and Mr. Stutchbury have found the remains of two saurian animals, to which they gave the names of Thecodontosaurus and Palæosaurus.* From the difficulty of assigning a precise date to this conglomerate, its relative age, as regards the period occupied by the accumulation of the new red sandstone series, is not clear; but we may, at all events, regard this reptile as having found the necessary food in the adjacent district. We may further infer that others of the like kind existed also in the neighbourhood; and we have evidence that a somewhat wide-spread area on the north, in front of the May and Malvern Hills, was tenanted by fish. So that, though the peroxide of iron was unfavourable to the existence of many marine creatures, the shores may have still had some animals living upon them, and the sea not have been so completely devoid of

* Geological Transactions, Second Series, vol. v. p. 349. These saurians are also noticed by Prof. Owen in the Report to the British Association on British Reptiles, 1841.

animal life during the whole period as not occasionally to have presented fitting conditions for the presence of fish.

Oolitic Series.

Many inequalities of the older and disturbed rocks are found to have been covered over during the accumulation of the last series; and there is good evidence of the like kind, showing that, at least, up to the inferior oolite inclusive, the lower members of the oolitic series in some localities overspread and came into contact with these older rocks, the same alteration of the relative level of the sea and land continuing as during the formation of the poicilitic series. A great change had, however, taken place in one respect: the supply and distribution of peroxide of iron, which so characterised the great mass of the new red sandstone deposits, now ceased, and, instead of this substance, calcareous matter was supplied and disseminated over a wide space, in some places having evidently advanced beyond the confines of the line bounding the prior accumulation of the poicilitic rocks.

There was reason to consider that beaches were formed along the shores of the dry land of the time, as this dry land became depressed relatively to the sea level during the accumulation of the poicilitic series; and we should consequently expect, if the depression were continued, that there would be some evidences of beaches or shingles formed where the breakers of the lias time could freely act. Fortunately, there is evidence of this kind; and we discover conglomerates reposing upon the slopes of the older rocks and spread over portions which may have been shallow bottoms, or properly situated for the accumulation of shingle, as Dungeness is now, where several hundred thousand tons of shingle are annually added, from its position relatively to the prevalent breakers, in a general horizontal direction seaward. These conglomerates, which it would otherwise (except when they contain organic remains) be difficult to distinguish from those which preceded them during the poicilitic period, have not the cementing matter coloured by the peroxide of iron, which previously, from being so abundantly disseminated in the waters of the time, entered frequently, though by no means constantly, into the cement of the dolomitic conglomerates.

Beginning with the lias on the west, we find it resting on upturned and disturbed carboniferous limestone, from the mouth of the Ogmore to Cowbridge, the lias spreading out beyond a narrow strait of it on the north of Colwinston towards Ewenny on the west, and Llangan on the east. In the latter part especially a thick conglomerate, composed of rounded pebbles and fragments of the subjacent carboniferous limestone, forms the base of the lias, here and there presenting a seam of

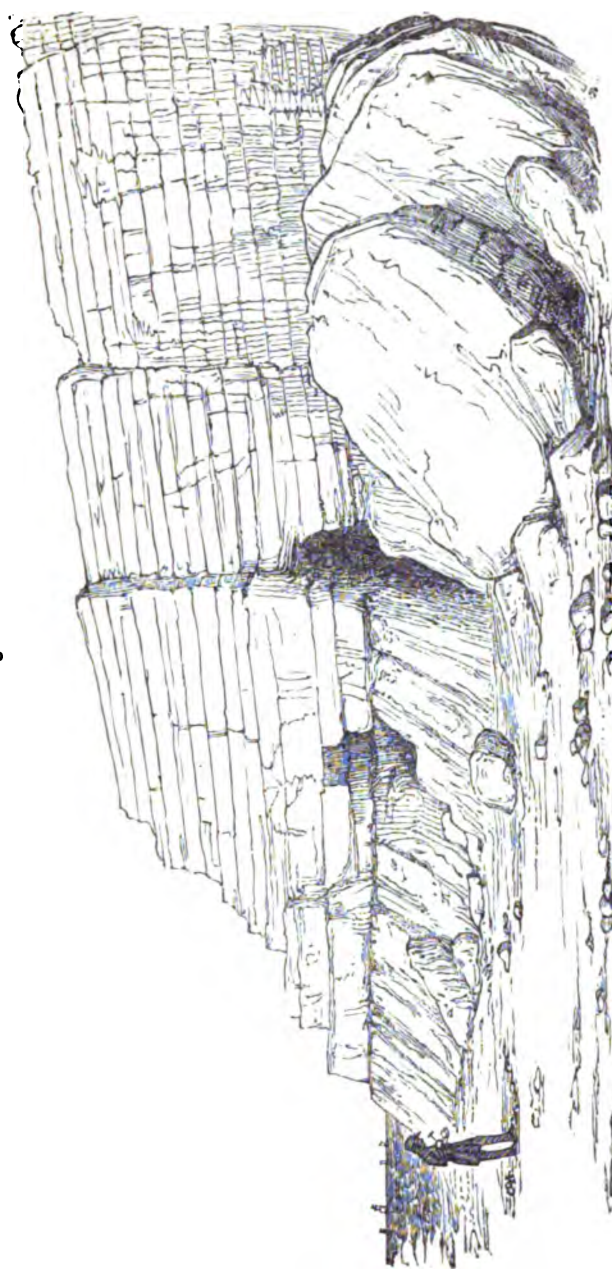
shale or limestone containing the *Gryphæa incurva*. As with the dolomitic conglomerate and limestone, so with the lias conglomerate and limestone—as the cementing calcareous matter prevails in the lower accumulations, the more do they form limestone beds. A very common form, when the conglomerate is not abundant, is that of a limestone containing disseminated fragments of the subjacent carboniferous limestone. In some localities we scarcely know where to draw the line between the dolomitic and lias conglomerates. We can easily conceive that one part of a mass of shingle and fragments may have been formed at the end of the one epoch, and another part at the commencement of another, the same general physical causes for the production, accumulation, and consolidation of the gravel and fragments continuing in particular localities.

Within a few square miles of this part of Glamorganshire we observe many variations in the lower part of the lias. Near Pyle, and thence to Bridgend, it reposes on marls or sandstones of the poicilitic series; and there we have argillaceous limestones and calcareo-argillaceous shales as a base, there being no beach or accumulation of gravel among the interstices of which the matter of the lias deposit could enter, but, as it were, sands and mud in deeper water. A state of things readily comprehended when we stand on a coast and observe a shingle beach, and even much accumulation of shingle on shore, and know that there are sands seaward, with mud still further out, and then suppose the whole depressed so as to be brought beneath any fine deposit, partly chemical, partly mechanical, such as the lias, when the conglomerate would cease with the beach, and the calcareo-argillaceous deposit would be spread in a sheet over the sands and mud. From the very fragmentary state of the pieces of carboniferous limestone in some of the lower lias limestones, we might not greatly err, probably, if we considered the depression to have occasionally included low land behind the shingle beaches, the deposit of the time mingling with the older rocks previously broken up on the surface by atmospheric influences, and not sufficiently exposed to rounding by attrition before they were enveloped by the matter of the new deposit.

Be this as it may, the variable sea conditions, such as many a coast now presents, seem somewhat obvious, and as any older consolidated rock might be covered as well as another under the needful conditions, we find the dolomitic conglomerate as equally overspread by the lias as the carboniferous limestone, as may be well seen at Newton Down, west of Bridgend, and in the vicinity of Cowbridge.

The vicinity of Dunraven Castle affords excellent opportunities for studying the contact of the carboniferous limestone and lias, with the exception of the larger masses of lower lias conglomerate. In the sketch opposite (Fig. 32) the lias is seen to repose quietly on the up-

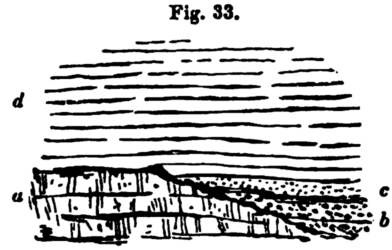
Fig. 32.



Lias resting on Carboniferous Limestone, Dunraven Castle, Glamorganshire.

turned edges of the former, a somewhat level line being continued for a short distance. Beyond the point formed by the bending of the coast the base is, however, more uneven, as shown beneath (Fig. 33).

Fig. 33.



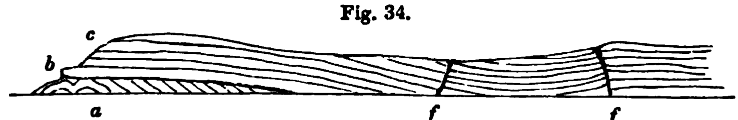
a, carboniferous limestone, nearly horizontal locally upon a curvature; *b*, conglomerate, probably lias conglomerate; *c*, a variety of the lower lias, named Sutton stone; *d*, argillaceous limestone of the lias.

Here a small portion of conglomerate is seen beneath the variety of whitish lias, commonly known as Sutton stone (from having been formerly much worked at Sutton for architectural purposes), which is found so abundantly to occur at the lower part of the lias in this vicinity. This bed, or beds, for occasionally there are several of them, is well seen in the same line of coast still further west towards the mouth of the Ogmore, resting upon the carboniferous limestone. In some localities it is dolomitic, and at Candleston, on the opposite side of the Ogmore, a variety, with small cavities, often the casts of shells, is very plumbiferous, galena being distributed through it, and even filling up the cavities left by the disappearances of the shells. Above these light-coloured or Sutton-stone beds, we find the ordinary argillaceous limestones of the lias with, however, comparatively little mixture of marls. Indeed, at Merthyr-mawr, not far distant, on the west bank of the Ogmore, the lias so resembles the carboniferous limestone on which it rests, that when the curvatures of the latter bring portions of it into a nearly horizontal position, and this kind of lias reposes upon it, it is only by a very strict search for organic remains that the difference can be found, especially as in some situations the lias, from the presence of an abundance of pentacrinites, has the encrinal aspect of so much carboniferous limestone. Other instances of this kind of lias are observable in the vicinity, pointing to the absence of the mechanically suspended mud, so commonly mingled with the ordinary lias limestones, in fact to a somewhat more clear condition of the water in which this portion of limestone was formed.

The point of land on which Dunraven Castle stands well exhibits the inequality of the carboniferous limestone at the time of the lias deposit, as also the brecciated condition of the lower beds of the latter, and the

filling up of the cavities in the former by them. The following (Fig. 34) is a general section from the point inland.

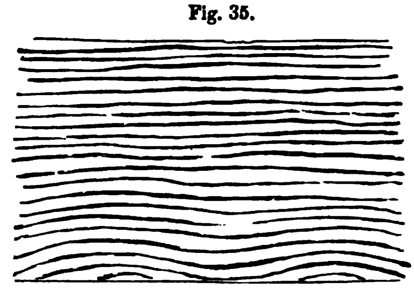
Fig. 34.



a, contorted carboniferous limestone; *b*, light-coloured lias, containing fragments of the subjacent carboniferous limestone; *c*, argillaceous gray limestone; *ff*, faults, traversing the lias.

Eastward from the castle, and not far distant, a good example of the adjustment of the lower lias beds to the irregularly formed ground beneath may be observed, the beds becoming more horizontal as the deposit continued, slight thickening of the subsequently formed beds, around the dome-like first adjustment, producing a nearly level surface. The following is a section of the cliff above one of these inequalities, showing the gradual approach to horizontality.

Fig. 35.



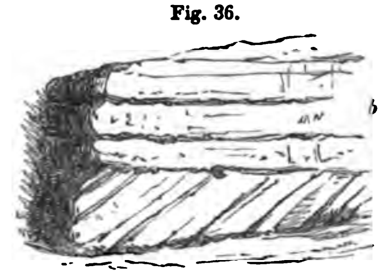
Though the mode of occurrence of the lias limestones for 16 miles on the coast of Glamorganshire, and the action of the heavy breakers rolling in from the Atlantic bare the rocks in a manner so favourable for observation, the amount of organic remains detected in this lias is by no means considerable. Groups of *Gryphæa incurva* and *Plagiostoma gigantea* are occasionally seen arranged as if they were still living on the top of the beds, the individuals of different sizes, from age. Long plants are also here and there displayed, little injured by attrition, pointing to quiet transport to the places where we now find them.* These and

* Near Dunraven we found sulphuret of lead entering into the joints of these fossil plants, in the same manner that sulphuret of iron is often seen. The plumbiferous character of the rocks in this locality is interesting. Strings of galena are observed in the carboniferous limestone occasionally; indeed a lead lode which has been worked at Gelli arail on the E.N.E., is prolonged to St. Bride's Down. Sprigs of the same ore are distributed here and there in the dolomitic conglomerate of the new red sandstone series. Galena is found, as above remarked, in the Sutton stone of Candleston, and in the locality mentioned in the text it enters into the joints formed in the jet-like plants contained in the beds of gray lias limestones.

other organic remains are, however, far from common, and hitherto few bones of those saurians which so abound in the lias of many parts of Somerset and Dorset have been discovered, as if the ancient coasts hereabouts, at the time of the lias, were less suited to these reptiles than those to the eastward and south-east

Proceeding hence eastward, we find the lias resting upon and surrounding the inequalities of the older rocks still protruding above the general level of the poicilitic deposits. The following section (Fig. 36), at

Fig. 36.



the entrance of Cowbridge from Bridgend (*a*, being carboniferous limestone and *b*, lower lias, formed of fragments of the subjacent rock cemented by whitish and grayish-white limestone), shows the same kind of fact, as is exhibited at Dunraven; and at Llanblethian, half a mile more southward, a ridge of carboniferous limestone rises conspicuously above the lias, which folds round it. Abundant instances are afforded in this neighbourhood for seeing the lias resting on the older rocks, the dolomitic conglomerate inclusive, and good examples of the Sutton-stone variety will be observed near Welsh St. Donats. At Michaelston the lias reposes directly upon old red sandstone.

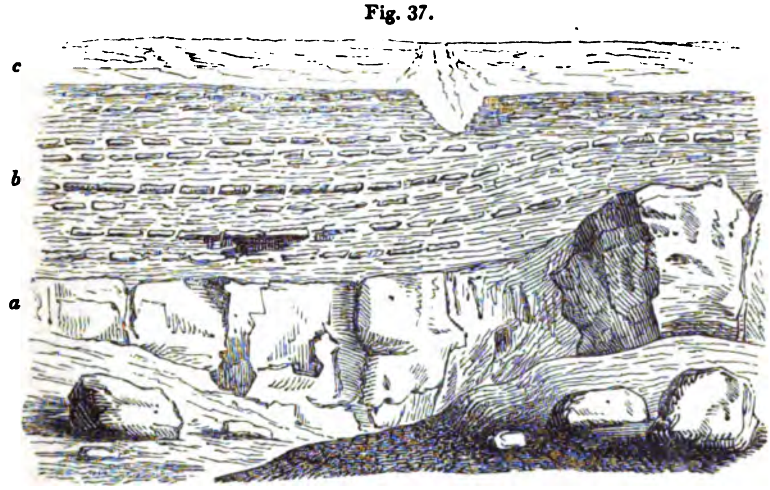
Towards Cardiff the lias covers the red and variegated marls (section p. 253),* but is again found overspreading these marls on the east of Newport, Monmouthshire; resting upon old red sandstone at Liswery, Llanwern, Langstone, and Bishton. On both sides of the Severn at the Old Passage the lias reposes on the variegated marls (section p. 253), and passing up the same river to and beyond Gloucester it occupies the like position, the western boundary line of this deposit retreating from that of the older rocks, at the same time that the outlying patch of Berrow Hill, about two miles from the southern termination of the Malvern Hills, shows that the lias once extended further westward than it now does, denudation having removed much of it in that direction.†

* Horizontal Sections of the Geological Survey of Great Britain, sheet 11.

† The lias of this district is observed to be disturbed by faults; one is to be seen near Barry Island, by which the new red marls and lias are tilted in a marked manner.

To the eastward, near Gloucester, we observe the top of the lias and its covering of the other members of the oolitic series, and see that the lower portion, composed of alternations of gray argillaceous limestone and marls, each commonly in thin beds, is surmounted by a fair thickness of marls, in which there is occasionally a thin bed of similar limestone, with disseminated nodules of the same substance. These, in their turn, are covered by a sandy, marly, and calcareous deposit, to which the name of *Marlstone* has been given, and which contains numerous fossils. Above the marlstone, marls or clays again come in, and in them interrupted beds or lines of argillaceous limestone nodules occur. The sketch beneath (Fig. 37), by Mr. Bristow (of the Geological Survey), of the *Upper Lias*, as it is termed, shows this rock as exhibited in a quarry near Wooton-under-Edge, with the manner in which the lines of flat argillaceous nodules are found, *a a* being marlstone, *b b* the upper lias, and *c c* common surface accumulation.

Fig. 37.



Returning towards the southern country, we find the lias constantly covered by the lower members of the oolitic series, to and beyond Bath, the upper lias gradually decreasing in thickness, so that at Tyley Bottom near Wooton-under-Edge, it disappears, and the marlstone and the sands of the inferior oolite above come into contact. The marlstone itself afterwards becomes less constant towards Bath, so that, near the latter place, there is some difficulty, locally, in seeing that it is present, a difficulty arising often, probably, from being sometimes unable to separate it clearly from the sands of the inferior oolite in such situations. On the west, we find that the lias sometimes rested upon the variegated marls of the poicilitic series, while, at others, it was deposited directly

on the older rocks, having overlapped those marls. Both modes of occurrence are well seen down the range of country between Purton Passage, on the Severn, and the neighbourhood of Bristol. Near Wickwar the overlap is easily observed, and it continues thence to Chipping Sodbury. On the west side of the coal field the lias rests on carboniferous limestone, from the vicinity of Alveston to Redlands, near Bristol. It seems evident that the lias in the east and west of the coal field, extending from Cromhall, on the north, to Brislington on the south, once spread over a shallow basin of the new red sandstone rocks, covering that coal field, and that these patches of lias have been separated by denudation.

This portion of country affords an interesting example of continued depression, bringing projecting portions of older rocks, remaining above the deposits of the poicilitic series, at its close, in such a manner beneath the accumulations of another and succeeding series of beds, that the whole became covered up, the lias, in this case, reposing on both sides upon portions of carboniferous limestone, which rose above the higher parts of the new red sandstone series.* Similar facts are observable still further southward, where, according to the portions of older rocks projecting above the general level of the highest beds of the new red sandstone series, the lias rested either upon such older rocks, those not too elevated to be thus covered, or upon the deposits which immediately preceded it. The changes which can be observed within a few miles, between the lias of Dundry Hill and its vicinity, resting on variegated marls, and that which, at Downside and Broadfield Down, near Wrington, is deposited on carboniferous limestone, are highly instructive, pointing to a gradual loss of the fine mud, mixed with the ordinary lias limestone, towards the west, so that, at Downside and Broadfield Down, the limestone presents many of the characters of the Sutton stone,† occurring under similar conditions in Glamorganshire. This absence, or less abundance, of mechanically suspended matter is not always observable where the lias reposes on carboniferous limestone,

* See Horizontal Sections of the Geological Survey of Great Britain, sheet 14, section 3.

† The following is an analysis of the Downside lias, made by Messrs. Cooper and Ransome, at the Museum of Economic Geology:—

Carbonate of lime	92·58
Carbonate of magnesia	0·32
Carbonate of manganese	0·55
Carbonate of protoxide of iron	0·34
Protoxide of iron	0·21
Silica	4·80
Water	0·50
Loss	0·93
	100·00

for near Bristol, at Alveston, and some other localities, marly and ordinary argillaceous lias limestones are common, close to the carboniferous limestone.

Another modification of lias is found on the skirts of the Mendip Hills, near Harptree, and at Chewton Mendip. The characters of these beds were pointed out by Dr. Buckland and Mr. Conybeare in 1822.* The accumulation may be regarded as an arenaceous deposit on clay, the whole resting on carboniferous limestone. The upper or arenaceous beds have been so impregnated with silica, that a kind of arenaceous chert is the result, some of the cementing matter being so highly charged with peroxide of iron, that, upon decomposition of part of the rock, excellent yellow ochre is obtained by the ordinary washing and depositing processes. Many parts of the arenaceous portion are full of organic remains, several of which are found in another and somewhat similar modification of the lias observed at Chewton Mendip, partly resting upon carboniferous limestone and partly upon dolomitic conglomerate. In this patch we fortunately perceive that connexion of the beds with the ordinary lias, which is not shown at Harptree. Though the lower beds are, like those of Harptree, arenaceous, this character becomes gradually lost in the ascending series, though cherty matter is found higher, and seams of chert are observed to be mingled with the argillaceous limestones, reminding us of the siliceous impregnation of the lias in parts of Glamorganshire. These seams of chert are valuable, as showing that the siliceous deposits were contemporaneous with those of the calcareous matter and fine mechanically suspended mud, so that we may more safely consider the infiltration of silica among the sandy beds of Harptree as of about the same date.

Passing round the eastern prolongation of the Mendip Hills, we observe lias conglomerates, in several places resting upon the carboniferous limestone, as, for example, in Vallis Vale, near Frome, at Nunney, and other places, such conglomerates being known by the organic remains detected in them. Near Shepton Mallet, where they have been pointed out by Dr. Buckland and Mr. Conybeare,† they are in considerable abundance, the more common lias reposing on them, and the pebbles for the conglomerate being furnished by the subjacent carboniferous limestone. We have the same fact exhibited here as noticed in the neighbourhood of Bridgend and Cowbridge, in Glamorganshire, similar physical causes having produced like results in the two localities.

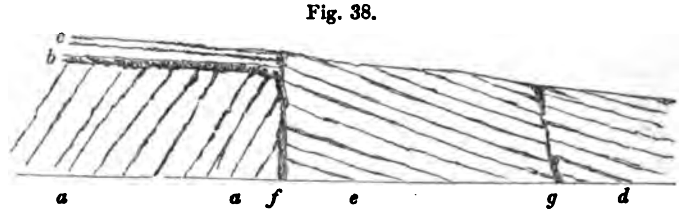
Not only do we see the same kind of conglomerates, but the beds of the lias also are thicker than common, and to a great extent free from

* Observations on the South-Western Coal District of England, Geol. Transactions, Second Series, vol. i. p. 294.

† Ibid., p. 303.

an admixture of muddy sediment, at least those beds which immediately adjoin the carboniferous limestone, for, in their prolongation southwards, the muddy matter is, as usual, mingled with the calcareous. An excellent section (Fig. 38) of a thin gravel base to the lias, and of some of these thick beds of lias, is observed on the rise of the hill out of Shepton Mallet, on the Bath road.

Fig. 38.

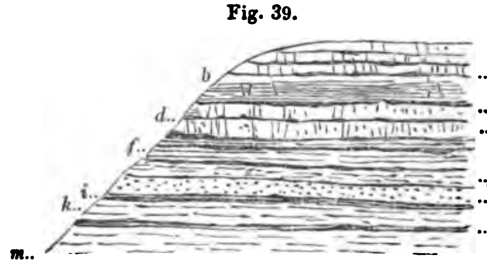


a a, carboniferous limestone; *b*, lias conglomerate; *c*, thin beds of lias; *e*, thick beds of lias, brought against the carboniferous limestone by the fault, *f*; *d*, in part, a higher portion of the same thick-bedded lias, brought down by the fault, *g*.

At Downshead Quarry, not far distant, there is another junction of the lias and carboniferous limestone, where the former is observed to be of a very light colour. At Downside, near Shepton Mallet, the lias conglomerate, mingled with sand, is very little consolidated in some places, but it fortunately contains the fossils of the adjacent lias.

To the southward of Shepton Mallet the lias rests on the red and variegated marls, so that red and variegated mud only rose, at the time of the lias deposit, up part of the southern flank of the Mendip Hills in this locality, and the lias, covering this mud, overlapped it, and rested on the adjacent carboniferous limestone. The following section (Fig. 39), observable on the south of Croscombe, will show the absence of the conglomerates where the lias rested on the red and blue mud of the preceding deposit, as also the kind of lias first thrown down upon the red marls close to Shepton Mallet.

Fig. 39.



a, gray lias limestone and marls; *b*, earthy, whitish limestone and marls; *c*, earthy, white lias limestone; *d*, arenaceous limestone; *e*, gray marls; *f*, blue marls; *g*, red marls; *h*, sandstone, with calcareous cement; *i*, blue marl; *k*, red marl; *l*, blue marl; *m*, red marls.

Not only does the lias repose on the carboniferous limestone near Shepton Mallet, but it rests also directly, on the north of that place, upon the old red sandstone, at the period of the lias sufficiently beneath the level of the sea to be so covered. In like manner, also, it covers the same rock near Wells; in fact, sometimes enveloping the old red sandstone, and at others the carboniferous limestone, as these two older rocks were equally reduced, by prior denudations, to the same general level required for the lias deposit.

If the lias continued to overlap the new red sandstone boundary against the Mendip Hills, round from Wells, by Uphill and Locking, to Harptree, the connecting portions have been removed by subsequent denudations; and we shall have occasion to point out that this district may locally have lost much rocky matter from that cause even so early as the formation of the inferior oolite. The various patches of lias on the south, west, and north of the Mendip Hills, show that these hills were surrounded by a sheet of that rock, now broken up into minor pieces by the removal of the intervening portions. These were the deposits of the time above the red and variegated mud previously accumulated, continuations of them resting directly upon the flanks of islands, as it were, of older rocks rising above such mud.

Still further south we find the lias, in a solid, uninterrupted sheet, continued southward to the coast in the neighbourhood of Lyme Regis, disappearing on the éast beneath a covering of oolitic rocks, and on the west broken into an undulating and uneven line above the upper beds of the new red sandstone series. The denudations of the Blackdown Hills, and of their extension in one direction towards Sidmouth, and in another towards Lyme Regis, enables us to see the boundary of the lias at the time when superjacent upper green sand was deposited.* A detached portion is found north-west of Bridgwater, a kind of island continuation of the long lias promontory extending from Butleigh to Puriton, still farther outlying portions of which occur at Watchet and near West Quantock-head. The most western portion of lias on the north-western coast of Somerset, is found near Selworthy; and here it has overlapped the poicilitic rocks on which it reposes on the S. W., resting on the Devonian rocks on the N. E.

It has been stated that, near Bath, the lias is covered by marlstone, which should be considered as a member of the lias, since it is covered towards the north by the beds termed upper lias, and by the sands of the inferior oolite. Quitting the vicinity of Bath, and proceeding towards the range of the Mendip Hills, the marlstone disappears, and subse-

* By reference to the maps, this line will be found to extend from the coast between Axmouth and Lyme Regis, by Axminster and the head of the Yarcombe Valley to Anger's Leigh, on the south of Taunton.

quently the sands of the inferior oolite; so that the inferior oolite itself rests on the lias. At the same time, it is not clear that in the neighbourhood of Radstock we have not a series of beds which may represent the inferior oolite, the marlstone, and the lias, the inferior oolite sands having fined off, and the marls of the lias becoming of less importance: in other words, that the sands were not deposited, and that the mud was transported to, and thrown down in this part of the district in less abundance.

From Kilmersdon and Mells to the neighbourhood of Shepton Mallet, the lias is overlapped by the inferior oolite; so that little else than the conglomerate beds previously noticed are to be seen. Near the latter place it is first seen emerging from beneath its covering of inferior oolite, and afterwards with the sands of that rock interposed. At Batcombe the marlstone is well seen, containing oolitic ironshot grains and being very fossiliferous.* Thence the same rock, modified in lithological structure, compact limestones entering into its composition, as near Alham and Westcombe, can be traced beneath the sands of the inferior oolite, by Week Champflower and Castle Cary to the southward. An outlying patch of the marlstone may be seen above the marls of the lower lias, forming the summit ground of the hill extending from Dicheat to West Pennard, in one place covered by the sands of the inferior oolite; and another outlyer supports the same sands, which, rising in a conical form, constitute the top of the well known and far seen Glastonbury Tor.

The section on the coast near Lyme Regis, exhibiting a thickness of about 600 feet, shows, beneath a covering of sands and sandstones of the inferior oolite, about 480 feet of marls, with some indurated beds, argillaceous limestone bands, and lines of nodules, covering 100 feet of alternating argillaceous limestones and marls, the lower 18 feet being a yellowish white and earthy limestone. Under this there are dark-coloured marls, with some gray limestones for 12 feet, the whole resting upon seven feet of dark slaty marls.†

* The following is the section seen at Scale Hill, Batcombe, near Bruton:—

	Feet.
1. Forest Marble (part only seen)	42
2. Fuller's earth (upper)	133
3. Fuller's earth rock	25
4. Fuller's earth (lower)	21
5. Inferior oolite; upper part, rubbly limestone; lower part, oolitic.	55
6. Sands and sandstones of the inferior oolite; interposed thin seams of blue marl near the top	66
7. Marlstone; argillaceous limestone replete with iron oolitic grains, very fossiliferous	21
8. Lias marls (thickness not seen)	

† For a detailed section of these beds, and lists of the organic remains found in the lias of Lyme Regis, see Geological Report of Cornwall, Devon, &c., p. 222–226.

Taking a general view of the lias mentioned, we find that in certain localities in Glamorganshire, Monmouthshire, Gloucestershire, and Northern Somersetshire, it spreads beyond the limits of the previous accumulation of the new red sandstone series, while in others, as in Southern Somerset and Devon, we have no evidence that it passed beyond that line at the time of its deposit, though we have evidence that at the period when the lower green sand was accumulated in the southern part of the district, the lias then, however the circumstance may have been due to previous denudation, was considerably within the western boundary line of the poicilitic rocks, since these upper green sands, overspreading both rocks, show their surface condition at that time.

Conglomerates point to the gravel condition of the first-formed lias in several localities, from the continuation of so much of the same physical causes as produced gravels resting on the older rocks at the period of the new red sandstone; and we can readily understand that these gravels were formed on coasts and consolidated by the same sedimentary and calcareous matter which covered the red and variegated mud in deeper water, or in more sheltered situations. Thus the gravels do not disprove the generally tranquil deposit of the lias, apparently required by its composition and mode of occurrence.

In a few places in Glamorganshire and Somerset, we appear to have proof that the waters in which the deposit was effected were clearer, locally, than the general character of the lias, over a wide space, would seem to indicate. As a whole, we have to look for the transport and deposit of much fine mud into the general area, to account both for the marls and the character of the limestones; and this not for a limited area, such as that under notice, but extending over a large part of England and into the continent of Europe. There was, therefore, no mere local change at the close of the poicilitic period, but the prevalence of some wide-spread similar causes, producing similar general effects.

Confining ourselves to the district before us, we find a conglomerate condition of beds extending even beyond those above noticed, and appear to have evidence that in a few localities, as for instance at Aust Cliff, on the Severn (p. 253), some indurated beds in the subjacent marls were partially broken up and rolled into pebbles, forming the bottom of the sea, as increase of depth permitted, inhabited by saurians and fish, which have left their droppings in abundance to mark their frequent presence. By reference to the Garden on Golden Cliff section (p. 261), it will be seen that about the same time sands were thrown down not far distant, with which the scales of fish were mingled in considerable abundance.

The conditions for this kind of detrital accumulation appear not to have long continued, not sufficiently long to produce any great

deposits; and we observe above it a thickness of black mud, rarely exceeding twenty feet, in which patches of various magnitudes and forms, composed of an abundance of coprolites, mingled with saurian and fish bones and teeth, mark the presence of these animals locally in large numbers for a long-continued time. We have proof of this kind of deposit from the coast of Devon to Glamorganshire and the banks of the Severn, much carbonaceous matter being mingled with the mud, so as to give it a dark or black appearance, and the chemical conditions having been such that iron pyrites was common, as often also sulphate of lime in finely disseminated crystals. Since irregular coprolite-bearing patches, in these dark marls, chiefly in the lower part, show the frequent presence of saurians, we may conclude that mud was not distasteful to them; and it may be here remarked, that we have often observed the caimans of Jamaica wallowing in the mud of large shallow lagoons, their bodies half buried in it, and the tip of their snouts at the surface of the water for breathing purposes.*

Though calcareous matter was occasionally introduced amid the mud, sufficient to form thin bands of argillaceous limestones in some situations, the black mud had ceased to be generally deposited before the bicarbonate of lime was carried by the water in sufficient abundance to produce often repeated limestones. In many localities the calcareous deposits which succeeded the black mud, with its occasional intermixture of gray, impure limestones, were of a light colour, though earthy. This character is very common from the coast of the English Channel to the Bristol district, the minor features modified, though the general fact is sufficiently marked.

Higher in the series a gray tint prevails, and we have a marked accumulation of mud and calcareous matter, sometimes the one prevailing, sometimes the other, so that the sea was sometimes fairly clear when the calcareous matter was abundantly in solution, and turbid when the mud prevailed. The whole seems to point to much tranquillity; and we are not surprised to find the multitudes of organic remains in it preserved in sharp and excellent condition. Dr. Buckland, who was the first to notice coprolites, has shown that these bodies frequently occur in patches of small thickness, more, however, in the marls of the higher part of the lias, than in the lower beds, marking the congregation of saurians and fish, in particular spots, during the general accumulation; and that those bodies would require very great tranquillity for their preservation. The thickness of the lower lias limestones, as they are sometimes termed, is variable, pointing to the prevalence of a greater

* When hard chased, we have found them bury themselves in deep mud, and thus escape.

abundance of calcareous matter in one part than in another of the general area at the same period.

After a time, the presence and deposit of calcareous matter ceased to a great extent, and mud prevailed (eventually forming marls), in which nodules of argillaceous limestone were sometimes formed in bands stretching over wide spaces, the nucleus of many of such nodules being often a fish, a shell, or a piece of wood. The thickness of this part of the lias appears to have varied from 200 to 400 feet, and in it we also discover numerous organic remains.

That the saurians sheltered themselves among, bred near, and commonly inhabited the shores of the lands which rose above the sea, such as the lands where the lias now nearly surrounds projecting portions of carboniferous limestone, appears probable. In the lias adjoining the shore-like flanks of the Mendip Hills, we discover an abundance of saurian remains. The extent to which any portion of the previously deposited new red sandstone series may have been raised above water as geological time rolled on, it may be difficult to appreciate, as we know not how much lias may have been removed westward by denudation, the Black Down Hills only showing its boundary in that district at the date of the upper green sand; but unless some of it were above water, we should have to conclude that the Ichthyosauri and Plesiosauri found so abundantly in the lias of Lyme Regis must have wandered far from land. The former of these reptiles was well constructed to do so, but the Plesiosauri would appear to have required sheltered places.

If we were to regard the general sea area as not diminished by some uprise of the poicilitic rocks above water, forming a low coast, the Pterodactyles discovered in the lias of Lyme Regis * must have wandered or have been driven many miles from dry land, and we can scarcely expect that these reptiles would have flown in this direction to cross to other land, since there would not appear to have been any on the east or south-east above water, and sufficiently near at the time. Upon the supposition, however, of part of the new red sandstone being above water in that portion of the district, the commencement of the continued uplifting on the west, which, through the accumulation of part of the oolitic series, produced a gradually diminishing sea space eastward, we should have to consider the clear overlap of the lower parts of the lias above and beyond the red and variegated marls in northern Somerset, Gloucestershire, Monmouthshire, and Glamorganshire, so that, according to this hypothesis, there would have been an upward movement

* Dr. Buckland has given a description of the Pterodactyle of the Lyme Regis lias, with general remarks respecting it in the Geol. Transactions, Second Series, vol. iii.

on the south not experienced in those situations. As we should have to infer the like for the lias northward of Purton Passage, up the valley of the Severn, and thus suppose that a central portion of country remained undisturbed, while both sides were uplifted, it seems more probable that the lias once extended far more westward, up to the older rocks on the south, than we now find it. Besides the eastern end of the Mendip range requires to have been beneath water when the inferior oolite there overlapped the lias, and spread over the old red sandstone and carboniferous limestone of that district.

The state of the sea during the formation of the lias presented a singular contrast with that during the preceding accumulations, judging at least from the occurrence of organic remains. Saurians and fish abounded, and cephalopods were numerous, belemnites swarming in some localities towards the close of the chief mud deposit. When the varied distribution of the animals existing at this time, and as marked by their remains, becomes studied with care, we may expect that many valuable inferences may be drawn as to the physical conditions of particular localities. Even now it is well known that some creatures were more abundant in one situation than in another, and some appear to have been limited to particular localities. Plants also are more common in certain situations, as if the course of their drifts, they being land plants, had taken particular directions, perhaps from the discharge of rivers outwards. Such inquiries, extending to the whole oolitic series, will be the more interesting, as this series constitutes the first deposit, after the great crumpling of the older rocks of this part of England and Wales, in which any quantity of organic remains is found; and hence the distribution of marine animals at equal times, due reference being made to the kind of deposit, would possess a high geological interest.

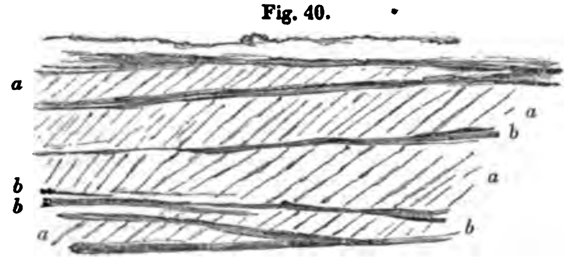
Surmounting the great mud accumulation, we find the beds named Marlstone presenting in one district a somewhat varied character, though generally marked by the presence of a multitude of organic remains. It is found more sandy, calcareous, or oolitic, in some places than in others, but at the same time it marks a change in the general deposits for a time, mud being less abundant. By the sections in the north, from the neighbourhood of Wooton-under-Edge, we see that the marlstone was covered by another deposit, closely resembling the subjacent lias, mud having again prevailed, so as to become much mingled with the carbonate of lime thrown down from the water; and we may here observe that, unlike so many parts of the carboniferous limestone, the lias can be regarded as very little formed of calcareous matter derived directly from the hard remains of marine animals, so that to account for the presence of carbonate of lime, we have to suppose its

solution, as a bicarbonate, elsewhere, and its introduction in such solution with the waters moving into the general area.

It would be premature, until the Geological Survey shall have completed a detailed examination of a wider space occupied by the oolitic series, to attempt a general view of that series in South-Western England. This, and an account of the cretaceous series of the same district, require for the present to be postponed. The modifications of both are highly instructive ; and we appear to have evidence that, while from emergence of the sea bottom, the deposits of the one gradually became less extended, a subsequent depression brought the cretaceous series over a large part of the district thus previously raised above the sea, outlying patches showing that the upper green sand even reached beyond Bide ford, resting on the coal measures of that vicinity.

While sheets of clay, widely spread, show times when fine mud was thrown down from mechanical suspension in water during the oolitic period, sands point to the drift of heavier detrital matter, and several of the limestones are but detrital accumulations either of shells, corals, or oolitic grains, so occurring as to show that they were propelled forward by the pushing action of water along the bottom. The beds known as the Forest Marble frequently exhibit a minor mixture of fine detritus, probably thrown down from mechanical suspension, with broken shells, fish palates, broken pieces of wood, and oolitic grains, sometimes strewed horizontally, but very frequently in a diagonal manner, showing the sweeping of loose materials on the bottom into a minor depression. The following sketch (Fig. 40) of the Forest Marble in the Butts

Fig. 40.



Quarry, Frome, is, on this account, extremely instructive, diagonally-parted beds, *a a a a*, composed of broken shells, fish teeth, pieces of wood, and oolitic grains, the various substances lying in the lines of the diagonal planes, so as to form good surfaces, being arranged as if the component parts were shoved over the more common horizontal planes of chief bedding (marked by the intervening clays *b b b b b*), when these drifts ceased for a time, and a quiet deposit of fine sediment in mechanical suspension was thrown down. These beds are seen to pass beneath others of sand, at the upper part of Frome, the sandstone marked by ripple or

friction ridges and furrows, there crossed by the tracks of marine animals which had crawled over the surface, one surface beneath the other at short depths, so that we have the markings of sea bottom over sea bottom. Such false-bedded accumulations of shells and grains of oolite, with drifted pieces of coral,* are not uncommon in other parts of the oolitic series, being observable in the great oolite about Bath (which, indeed, may be considered as little else than a modification of the lower Forest Marble of the south), in the inferior oolite of some localities, and in other parts of the series, which exhibits, as a whole, many minor alterations of sea bottom, a large proportion of the limestones being composed of the hard parts of marine animals, a character wherein they differ very materially from the lias limestones.

However tempting a brief notice of the modifications and succession of deposits forming a large part of the oolitic series from the vicinity of Stroud, on the north, to the country south of the Mendip Hills may be, we must for the present confine ourselves to a notice of so much of the lower beds as are modified by their approach to, or contact with the carboniferous limestone and old red sandstone of the Mendip Hills, as a notice of the facts connected with them tends to complete a general view of the manner in which these older rocks have been partially covered up, from the earlier part of the new red sandstone deposits to those of the lower part of the oolitic series, inclusive.

The modifications of the lias skirting, or partially resting upon, the older and previously disturbed rocks has already been noticed. The next deposits are those of the inferior oolite, a calcareous accumulation based on sands and sandstones, the latter forming indurated bands in the former, and occasionally arranged in planes of great nodules. These sands and sandstones constitute marked deposits on the north and south of the Mendip Hills, but they terminate short of them, so that the calcareous, or upper beds, of this division of the oolitic series overlap, and rest directly upon the carboniferous limestone and old red sandstone, in places spreading over and beyond the lias. The sands are observed to terminate, on the north, in the neighbourhood of Dunkerton, about seven miles from the Mendip Hills, and the isolated hills of the Sleight, near Timsbury, and the Barrow Hills, show how thin these sands were becoming in that part of the district. At Dundry Hill they are merely represented by about ten feet of sandy marls (p. 255), as if they originally fined off in that direction, the sand drift not having extended much farther to the westward. On the south the sands of the inferior oolite approach closer to the Mendip Hills, and

* An excellent example of diagonally-drifted corals, forming nearly horizontal beds by accumulation, may be observed in the forest marble, or upper part of the great oolite, near Bradford.

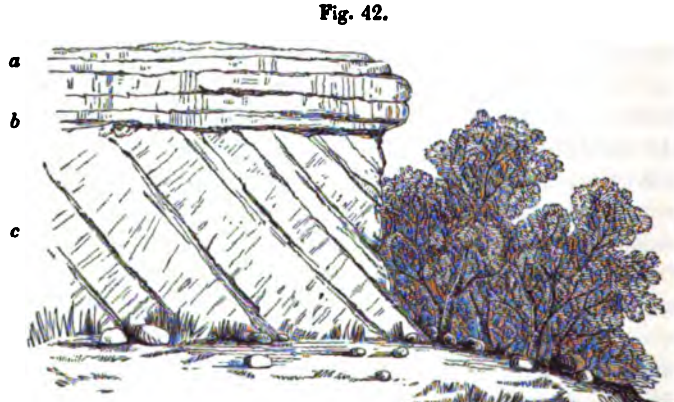
can be seen, thinning off more suddenly than on the north, to come within about a mile of the old red sandstone and carboniferous limestone near Shepton Mallet, resting on the lias and supporting the limestone of the inferior oolite which overlaps them. The summit of Glastonbury Tor shows that the sands of the inferior oolite once extended over that part of the district; and the summit of Brent Knoll, rising like an island out of the surrounding alluvial tract of the Bridgewater levels, also points to the extension of the inferior oolite deposit far more westward than would be otherwise evident.

On the north, after the termination of the sands, we have in the neighbourhood of Radstock, as also near Stratton-on-the-Fosse, some marked beds representing a kind of passage of the lias into the inferior oolite limestones, without the intervention of sands, as if the conditions for deposit were at that time so modified towards the Mendip Hills that calcareous matter was thrown down in that direction while sands were accumulating more northward. Be that as it may, by proceeding more southward we soon find the calcareous or upper beds of the inferior oolite resting directly on various previously consolidated rocks, and in a manner to show abrasion of the latter before they were incrusted by the inferior oolite. There is, however, one locality between Elm and Frome, on the north side of Vallis Vale, and about half a mile from the latter place, where we have some beds, reposing upon the upturned edges of the carboniferous limestone, that appear to form a kind of passage between the cherty and arenaceous variety of lias (such as is found near Harptree and Chewton Mendip) and the inferior oolite.

Between Vobster and Babbington the inferior oolite is observed to overlap the lias and spread over the coal measures and carboniferous limestone, and from Vobster to Mells and Elm, on the east, to rest upon dolomitic conglomerate. Vallis Vale and Murdercombe, as pointed out by Dr. Buckland and Mr. Conybeare, show the inferior oolite in nearly horizontal beds upon the upturned edges of the carboniferous limestone, with occasionally an interposed portion of a conglomerate referable to the lias, and containing organic remains. The annexed sketch (Fig. 41) of part of Vallis Vale will show this fact, as also the remarkably even manner in which the upturned edges of the carboniferous limestone have been worn away anterior to the deposit of the inferior oolite, a circumstance common to a somewhat extensive area on the eastern termination of the Mendip range, where covered by the inferior oolite. The same fact is well exhibited in Murdercombe, where the following section (Fig. 42) may be seen near the bridge.

Fig. 41.

Fig. 42.



a, inferior oolite ; *b*, a somewhat arenaceous parting ; *c*, upturned beds of carboniferous limestone.

From Whatley to Nunney and thence south-west, nearly to Broad Grove, the valley shows inferior oolite resting on carboniferous limestone, the bed of the oolitic series above the former (Lower Fuller's Earth Clay) overlapping it, and resting on the carboniferous limestone near the latter place. A line of junction between the inferior oolite and subjacent older rocks, partly carboniferous limestone and partly old red sandstone, can be traced for about four miles from Vallis Vale to Leighton, the inferior oolite on the north-east part being surmounted by the Lower Fuller's Earth Clay, and the Fuller's Earth Rock. Near Leighton the Lower Fuller's Earth Clay again appears to overlap the inferior oolite and to rest on the carboniferous limestone, but after a short distance the inferior oolite again emerges from beneath this covering, and is seen to rest upon the carboniferous limestone, as also a portion of old red sandstone, to and beyond Tansey.

Not only is a large portion of the area, wherein the inferior oolite is seen to rest on the carboniferous limestone, observed to have presented a marked even surface, viewed on the large scale, for the deposit of the former, but, throughout, this surface has been drilled into holes by lithodomous animals, which must have existed in the seas at the commencement of the inferior oolite. The holes, which were observed by Professor John Phillips, in 1829, are of two kinds, one long, slender, and often sinuous, extending several inches into the carboniferous limestone, the other entering that rock a short distance only. In the former we find no traces of shells, in the latter we often discover them, in the situations in which they lived. In both holes we find the matter of the inferior oolite, which entered them from above at the time of its deposit.

In some places the shells of oysters may be observed attached to the surface of the carboniferous limestone on which the oysters lived, and these are occasionally pierced through by the borers, which found such shells remaining on the rocks after the animals which constructed them had died, as we now observe on many sea coasts. On the top of the hill between Holwell and Leighton oyster shells, of the date of the inferior oolite, adhering to the old surface of carboniferous limestone, and occasionally pierced by borers, may readily be seen, and it is to be hoped that the locality may be so preserved from injury as to show this fact, which can be no where so well appreciated as on the ground.

The following sketches (Figs. 43 and 44) will show the manner in which the surface of the carboniferous limestone has been bored by marine animals of that period. The specimen represented by Fig. 43 was taken from beneath a mass of inferior oolite, removed for the purpose, so that no doubt should exist as to the geological date of the bored surface of rock, and the second (Fig. 44) shows the shell, considered by Professor Forbes to be probably a Lithodomus, still in its cavity.

Fig 43.

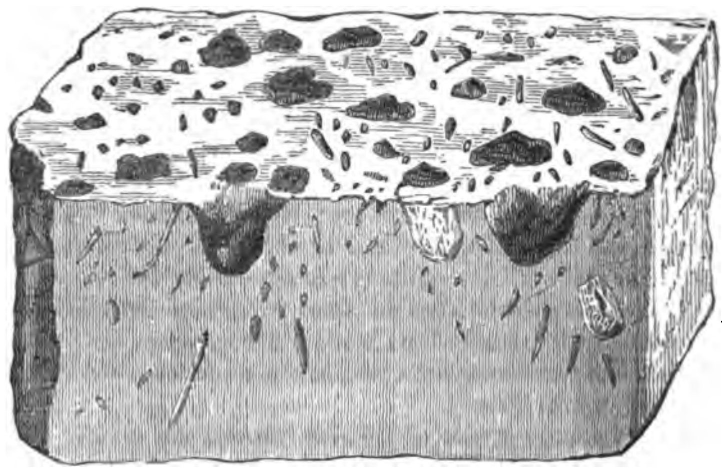
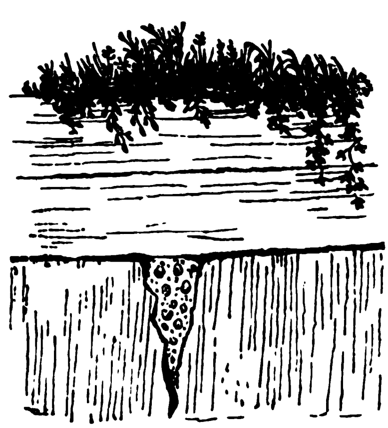


Fig. 44.

Not only do we observe the surface of the carboniferous limestone thus smoothed off and bored, but we also find that the conglomerates of the date of the lias have been worn down and the surfaces, so formed, bored. Among the examples of this fact, the following (Fig. 45), observed on the side of the high road between Murdercombe Bridge and Mells Green, may be considered as very instructive.

Fig. 45.



In this case inferior oolite (*a a*) rests on upturned beds of carboniferous limestone (*b*), which, being cut by the road somewhat in the line of strike, have there a fallacious appearance of horizontality. In the carboniferous limestone there has been a fissure (*c*), filled at the time of the lias by conglomerate, this conglomerate containing fish teeth, belemnites, and some other remains. The surface of the conglomerate and of the carboniferous limestone have been both bored alike, and by the two kinds of animals above noticed, and there seems little reason to doubt that the lias conglomerate, being consolidated at the time these borings were effected, the conglomerate was worn away with the carboniferous limestone, so that a common smooth surface was produced. Though the surface was thus often smoothed off, it was not always in the same plane, and many inequalities existed at the period when the inferior oolite was first deposited, and we find portions of more angular masses of the older rocks rising through the inferior oolite. As a whole, however, the rounding of the subjacent older rocks is somewhat marked. On the north of Frome, from Bradford's Bridge to Kersley's Mill, denudation shows a kind of outlying rock, composed of old red sandstone and carboniferous limestone, beyond the mass of the Mendip land, as it existed anterior to the deposit of the inferior oolite, forming a kind of ridge, running north-east and south-west, and which was once covered up by an incrustation of that rock as the ridge became depressed beneath the sea.

When we examine the composition of the inferior oolite we find it to vary in different places. In the vicinity of Doulting, on the south side of the Mendip Hills, broken pentacrinites and shells, principally the former, constitute a chief portion of it, and the same character is observable over that portion of country. Towards Frome the oolite grains are more abundant, and so continue towards Babington and Radstock. The accumulation may be regarded as to a great extent mechanical in the lower part, the upper portion pointing more to deposit from chemical solution. We have direct evidence that in some places, after a certain amount of accumulation and a bed had been formed, there was a state of repose, for in the upper part of some beds of the inferior oolite, succeeding each other, the surface has been bored by the same lithodomous animals which pierced the surface of the subjacent carboniferous limestone or lias conglomerate, as the case may be. This happened as well on the north side of the Mendip Hills, as on the south of them, and good instances of the fact are to be seen in the Doulting quarries on the south, and in some quarries close to Ammerdown, near Kilmersdon, on the north. The fact is, doubtless, somewhat general in this part of the district, and is valuable not only as showing the repose between the accumulations, constituting the different beds, each in succession being sufficiently consolidated to permit the boring animals to establish them-

selves on its upper surface, but also as pointing to the probable consolidation of many a bed in other parts of the oolitic series, prior to the deposit of another above it, where this kind of evidence cannot be adduced.

After the mechanical aggregation of the oolite grains, and broken pentacrinites, with the remains of the molluscs which lived in and upon this kind of bottom, had proceeded for some time, calcareous matter embedding a variety of shells prevailed, and a kind of nodular arrangement of parts constitutes the top of the inferior oolite near the Mendip Hills. The muddy matter forming the lower Fuller's Earth then spread over the calcareous deposits, and was succeeded, for a time, by a return of conditions similar to those during which the upper part of the inferior oolite was formed, and the calcareous deposit known as the Fuller's Earth Rock was effected. Muddy deposits were again formed over this accumulation and the upper Fuller's Earth covered the sea bottom of the time and locality; not, however, confined to it, for the mud then accumulated constitutes a marked sheet of fine detrital matter extending over a much wider space than the districts under consideration.

This mud may have been spread far more westerly than we now find any traces of it, and have been cut back to the range of cliff-like escarpments of the oolitic rocks, extending on the north and south of the eastern part of the Mendip Hills, by the action of the breakers falling on a line of coast now elevated above the level of the sea. The physical features of the country would appear to point to the protecting influence of the Mendip land, at its junction with this range of escarpments, at the time when the oolitic rocks were thus cut back and removed, for there the cliff-like character is less apparent, precisely as it should be on the supposition that waves rolled in from the westward and broke on such a coast.

Other changes, not less interesting, have to be noticed when sufficient country has been carefully examined to enable us to treat properly of the oolitic, cretaceous, supracretaceous, and more modern accumulations which have been effected in South Wales and South-Western England. Enough has, however, been stated to show that this small spot on the earth's surface, for such it is, has been exposed to many different modifying conditions during the lapse of the geological time already noticed. At first we find mud, sands, and gravels (for the most part exhibiting very gradual accumulation), and derived from pre-existing rocks, the detritus mixed with some calcareous matter, and the whole so mingled with igneous products as to render it scarcely doubtful

that volcanos rose above the surface of the sea in parts of the district, and that ashes were thrown out and lava currents ejected from them, intermingling with the common detrital deposits of the time. Various animals lived in and on the sea bottom of the period and were adjusted, as we now find such animals, to the conditions best suited to them, and as the accumulations continued many kinds perished and were replaced by others.

A time then came when the deposits of the district were intermixed with a large collective amount of peroxide of iron. The new state of the sea bottom was unsuited to the kind of animal life which previously so abounded, and except a few fish little else is found in the accumulations of mud, sand, and gravel now formed, and many thousand feet in depth, even allowing that the mode of deposit has been such as often to give a false appearance of thickness. Gravels became more abundant in the upper part of these deposits, chiefly though not altogether red, and calcareous, muddy, and arenaceous matter, not marked by any abundance of peroxide of iron, finally prevailed. Whatever differences and modifications there may have been in different parts of the general district while this mass of matter was accumulating, so that the peroxide of iron was more mingled with the deposits in one part of it than in another, and that conditions for the existence of marine animal life were favourable in one locality and unfavourable in another, the spread of the upper calcareous, argillaceous, and sandy deposits (however modified they may have been by differences in thickness or in the amount of one kind of accumulation more than of another), appears to have been general in those localities where any deposits were effected.

A third great change succeeded. As far as regards a large part of the district and for a long period little detrital matter derived from pre-existing rocks was drifted into it. Marine animals swarmed and left their harder parts to accumulate and form beds hundreds of feet in depth. Solid beds of limestone were produced partly from these remains and partly from the chemical deposit of carbonate of lime, itself, perhaps, in a great measure obtained from the solution of many of the harder remains of these marine animals. While the calcareous matter thus abounded in one part of the district it was more scarce in another, and common detrital beds were there formed.

The next and fourth chief change was of a most marked kind, and the manner in which it was effected varied in different parts of the general area. In places it was somewhat sudden, in others less so, and in one part of the district there were such alternations of calcareous, argillaceous, and arenacéous conditions that a considerable thickness of deposit is characterised by alternations of limestone, shales and sandstones, the whole fossiliferous. A large mass of vegetable matter, often

occurring in extended sheets of comparatively small depth, now became entombed, interstratified with mud, sand and gravel, much of this vegetation having grown above the peculiar beds over which we now find it in its present state of coal. Though many plants were drifted from some adjoining dry land, we find others, independently of the thin vegetable accumulations, now forming coal beds, standing where they grew, their stems rising amid the sands and mud with which they have been covered. No trace of a marine remain* has yet been detected in the many thousands of feet of depth of which these accumulations consist.

A great interruption of deposits now took place, and the accumulated sea bottoms, and the mud, sands, and gravel, with the thin sheets and intermixtures of vegetable matter, last noticed, were squeezed and crumpled so that they no longer occupied the same amount of superficial area. At no remote period from this, if not at the same time, masses of granite were thrust up in part of the district, forcing aside and even breaking through the detrital, calcareous, and igneous products of former periods. It is not improbable that molten trappean rocks may have been also thrust up in another part of the area, at or about the same time. This period of violence and disturbance did not terminate without numerous cracks and rents being formed as well in such parts of the granite as had become consolidated, as in the adjoining detrital and other first-formed rocks as had been displaced by it, and into many of such cracks fused granite was forced up from beneath. Great dislocations were then also produced, and it is not improbable that some even exceeding two thousand feet of movement vertically, as regards the planes of the beds, were then effected. Of the time which the disturbed ground took to adjust itself we possess no direct evidence. We can only infer that, while the folding of the beds is of such a character, in many localities, as to have required great lateral pressure to force them into the forms observed, and many cracks and fissures, into which fused rocks rose, were due to the shrinking of the heated masses from cooling, the various great and minor dislocations of this period were the adjustments of the disturbed masses to a state of repose.

We see in the next state of the district that comparative tranquillity had been again restored, and that gravels, sands and mud were accumulated in waters washing the shores of various portions of the disturbed and dislocated rocks which rose above their level. The deposits of this period like those of one previously noticed were characterised by the presence of a large amount of peroxide of iron, giving a red tint to

* The shells in this deposit, termed *Unio* by Sowerby, and referred to *Cardinia* by De Koninck, are not supposed to be marine.

the mass. As in the previous instance the remains of animal life can scarcely be found, and it is only towards the top, in a thin deposit of gray beds amid the red marls, which there prevail, and in the northern part of the district, that we discover the remains of fish and of a mollusc. Two saurians have also been found in the gravel of this period in one locality.

The sixth and last change we have now to notice, shows tranquillity still preserved, and the causes, whatever they may have been, for the intermixture of a large amount of peroxide of iron with the mud, sands and gravel of the time, to have ceased. Gray mud and calcareous matter are now spread, with certain modifications, over such parts of the district as could be thus covered, and life of a new kind abounded, different from that which, with a certain general character, prevailed among the older deposits, excepting in the few remains which, in this district, have been observed in the red deposits immediately preceding the lias. The most marked difference consists in the presence of huge reptiles which must have lived in multitudes in the seas and along the shores.

Of the various beds of clay, sands, and limestones of different characters, surmounting this accumulation, we shall not now speak, further than to observe, that although many of them, no doubt, extended much further westward than we now observe them, being cut off in that direction by denudation, the evidence is in favour of their having been, as elsewhere noticed, deposited in areas gradually diminishing to the eastward.

Coupling this district with Southern Ireland, we have, during the lapse of the geological time noticed, two instances, at different periods, one anterior to the deposit of the old red sandstone and the other subsequent to that of the coal measures, when great forces so acted as to squeeze, crumple up, and dislocate detrital, calcareous and igneous rocks, accumulated to the depth of many thousand feet, much of the pressure having been lateral over large spaces. In both instances, probably, an upthrust of granite, as also of some trappean rocks, accompanied these great movements in parts of the disturbed area. At other times we seem to have the evidence of the action only of such forces and causes of detrital, calcareous, and igneous accumulations as we daily witness.* Such differences as these are sufficient to show that, however desirable and necessary it is well and systematically to study all those causes of accumulations, zoological, botanical, chemical and physical, which in the present state of the world we either see or fairly infer do

* The faults and movements of the rocks of this district, subsequently to the deposit of lias, will have to be noticed in another memoir.

exist, we must also carefully bear in mind those other causes of modification and change which the form of our planet, and a multitude of geological facts, would lead us to consider must have most materially influenced the conditions of the earth's surface during the progress of geological time.

ADDITIONAL NOTE.

Coal Measures. When we regard the great area (see Physical Atlas of Berghaus and Johnstone, Hydrology, No. 5), extending from the country drained by the Volga, eastward, through eighty degrees of longitude, into China, and from which the waters find no course outwards to the main ocean, or to the seas connected with it, we appear to have before us such general conditions as, with proper modifications and combination, would permit the kind of accumulations observable in the extensive coal districts known to us, or which we may fairly infer once existed. The gradual depression of a large part of such an area, receiving an abundant supply of detritus from the rivers flowing into it, might readily take place to great extent without letting in the sea, and produce the effects noticed previously (p. 216). While this happened in one portion of the general area, and so that little else than fresh water entered it, (as if the great lakes of North America so evaporated that the surplus waters did not exist and find a passage over the bounding and elevated land), the sea might readily be more mingled with the accumulations of another portion. Many a shallow basin could thus get filled up to the height at which vegetation, requiring contact with the atmosphere, could flourish. Such shallow basins multiplied and depressed, so that mud, sands and gravels covered them up, the latter again crowned by vegetation, would not be at variance with the facts observable in our coal districts. In great areas of this kind where the drainage is not towards the ocean, the marine or fresh water condition of the interior sheets of water would depend upon the extent to which the main body of land had been raised from the bottom of an ocean, leaving an inland sea, to be gradually diminished by the excess of evaporation over the supply of water, or the dry land may have been depressed over an extended space, drawing a large part of the drainage waters towards the depression.

On the Denudation of South Wales and the adjacent Counties of England. By ANDREW C. RAMSAY, F. G. S., Director of the Geological Survey of Great Britain.

IT may be considered as an axiom in geology, that the materials of all sedimentary strata, mechanically deposited, have been derived from the wreck of pre-existing rocks. This waste and re-formation of rocks, is partly the result of atmospheric influences and the agency of running water, and also, to a great extent, is attributable to the ordinary destructive action of the sea on certain coasts.

The subject of this paper is intimately connected with the latter part of this proposition, in so far that many of the results sought to be explained and established, are referred to the influence of this powerful geological agent.

The effects of these influences vary in different parts of the surface of the earth, according to local conditions.

At periods within the range of authentic geological history, as exhibited in deposits which date their origin with the earliest known organic appearances, it is not impossible that the *intensity* of some of these operations may have differed from that which we now observe. Thus, for example, if it be supposed that at any time the atmosphere and the sea contained a greater proportion of carbonic acid than at present, then the disintegration of certain rocks must have been sensibly accelerated by the union of this acid with their alkaline constituents.

The dash of the sea on a line of cliff presenting the necessary conditions, would then more rapidly work its destruction than could now be effected on a similar line of coast under the same relative circumstances. But, as such a state of things cannot by possibility be allowed in more modern geological epochs, there is, therefore, no ground for supposing that during their continuance, the average effects and intensity of these causes on the general surface of the globe, exceeded those of which we now have every-day experience.

It is with these times that our argument is principally concerned.

It has been stated, that geology forms the basis of physical geography. The forms of existing coasts are readily referable to certain of its varied phenomena, such as the relative strength and durability of the materials opposed to the influence of the waves, the disposition of the rocks composing these formations, and their relative exposure to prevalent winds and occasional heavy gales.

The physical features of the interior of a country are equally the result of geological operations; the most important of which (at least in the country we are about to consider) are referable to a combination of causes, viz., the form its rocks have assumed from disturbance and contortion subsequent to consolidation, and the effects of the action of the sea on formations of various hardness, or which, from disposition arising from these contortions and other causes, offered different degrees of resistance to that action during sundry elevations and depressions of the ancient land; for, let it be distinctly understood that the great external features of the country under review are considered to be the result not of the inland influences either in operation now or at any past period of its history, but rather of the very influences even now modifying the form of our existing coasts—such influences acting over an indefinite period of past time, indefinite as regards our ordinary methods of calculation, but perhaps to a great extent definable within certain prescribed geological epochs. It will be hereafter shown, that the action of the weather and the power of running water, have only slightly modified the form the land assumed as it last issued from the waves.

But, to whatever causes the existing features of any country may be assigned, it is evident that without data by means of which we may form true conceptions of that form, it is impossible to reason correctly either of the manner of action of these bygone operations, or of the magnitude of their effects. Such data are to a certain extent supplied by the construction of geological sections on a true scale, vertically and horizontally, having for their base line the level of the sea. Without these, it is vain to attempt precise argument on a variety of phenomena, either as regards questions of physics or natural history. If a false scale be adopted, the form and elevations of the country, the thickness, inclinations, and general arrangement of its component strata, are all distorted, producing results equally exaggerated and irreconcilable. And, as a further consequence, it is impossible correctly to estimate the original extent of the broken and disjointed strata, and thus to attempt to form any approximate conception of the amount of matter destroyed and rearranged, during the processes that reduced them to their present fragmentary condition. During the progress of the Geological Survey of Great Britain, in South-Western England and in South Wales, a number of sections have been constructed on a true scale of six inches to a mile; and on evidence afforded by them the following reasonings are adduced.

What first strikes the eye on examining certain of these sections, is the remarkable curvature and distortion to which the strata composing all the formations, from the top of the coal measures downwards, have been subjected. Following these breaks and curves, the same series of rocks

are seen repeatedly to rise to the surface, sometimes in rapid, sometimes in wide-spreading undulations. When, in accordance with the curves indicated by surface dips, vast masses of rock are carried in these sections deep down into the earth, far below our actual cognizance, it is yet impossible to doubt their underground continuity, when we find again and again, the same set of beds diving downwards in one district, and (perhaps somewhat modified) again outcropping to the surface in remote parts of the country. The abuse of this fact, now familiar to every geologist, in earlier times led to the hypothesis of the original universal continuity of all strata over the entire circumference of the globe. But if the inference now drawn be legitimate, a little reflection will show, that in the case of curved and conformable strata, the same arguments that apply to the continuity of rocks below the surface, may often safely be employed to prove the original connexion of contorted strata, the upturned edges of which may frequently be far apart. Attention being given to the physical relations of all the rocks in any country, such restoration of masses of rock to the form they once possessed, is within the limits of safe inference. And if, in the cases above noticed, this original continuity of distant masses, and their spreading over tracts where they have left not a trace, be once granted, then the vast amount of matter we shall be able to show has been removed from such tracts, may well make us cautious in disbelieving the probable or possible destruction of other masses, once resting above the rocks that compose the present surface, but of the former existence of which above that surface, we have at first sight no direct evidence. Outliers, cape-like projections, and anticlinals of various strata, so common on our maps of geological England, sufficiently illustrate the first proposition; and the frequent occurrence of vast thicknesses of strata, disposed vertically or at high angles, afford perfect evidence that such strata were not originally discontinued at their present outcrop, since such supposition would involve the necessity of asserting, that the rocks in question were deposited in successive layers, forming together, at their extreme edge, a wall or highly inclined plane, often many thousand feet in height.

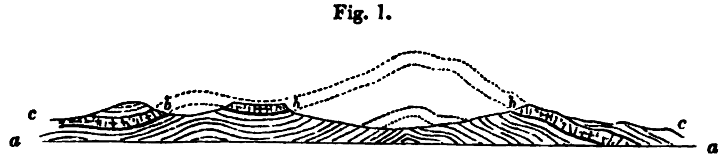
To treat the subject more in detail. Take, for example, Section No. 1, Plate 4, across the Woolhope district. The most inexperienced eye would scarcely doubt that the lowest beds of limestone immediately overlying the curved rocks beneath, were originally united by a certain amount of calcareous matter that has now disappeared; and so, by easy inference, the same conclusion is extended to the more distant beds, gradually receding to the banks of the Wye on the one hand, and to Ridge Hill on the other. This is the more positive, as it is, in fact, a section of a long roll in the strata, which extends for many miles further south, and in the dome-shaped end of which, at Wool-

hope, the old red sandstone beds having been more effectually cut away than at other parts of the curve, the underlying Silurian strata are extensively exposed. The same may be said of its Silurian subdivisions. All the greater divisions of the strata may, indeed, be traced entirely round the dome, like the concentric layers of an onion with one side partially removed.

Some of the other sections selected for illustration, afford the same evidence of original union of parts on a more extended scale. Of these the most illustrative are Sections No. 4, Pl. 4, across the Mendip Hills, No. 6, Pl. 5, across the southern part of Pembrokeshire, and No. 2, Pl. 4, from Cefn Crib, in Monmouthshire, to the Forest of Dean. In the districts through which these sections are drawn, no practical field geologist, accustomed to extended surveys, would doubt the once unbroken condition of their strata, and indeed (attention being given to the geological physics of the country, such as the tendency of certain rocks to thin out in given directions), it would almost be impossible to draw a line across any part of the older rocks of South-Western England and South Wales, in which similar phenomena would not present themselves.

The manner in which this restoration of a country is obtained, has been already alluded to, and is sufficiently obvious. The inclination or arrangement of the surface beds of conformable strata being accurately laid down, it is easy to infer their disposition when they dive beneath the surface, at any ordinary given depth, that, (when the thicknesses of the strata are known,) being dependent on the general curves the lower beds must follow, to be in accordance with the inclinations exhibited by those rising to the surface. These rules being applied to the "restoration" of rocks *above* the present outline of ground (by joining opposite and approximating dips, and so continuing till the more distant masses are united), an approximation to the form of the strata is gained, such as obtained, when, after deposition and consolidation, the greater disturbances occurred, that threw the strata, composing the country into their present general positions.

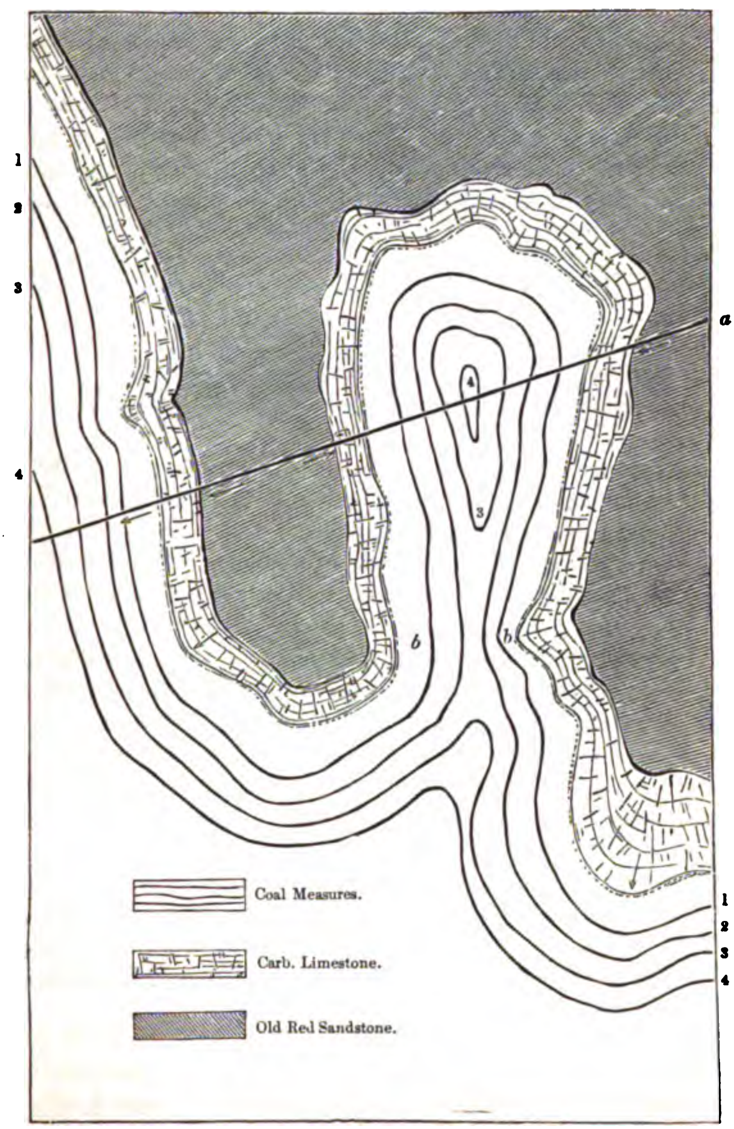
Fig. 1.



In the imaginary section, Fig. 1, let *a a* be the level of the sea, and *b b b* a bed of limestone, occasionally rising to and resting on the surface, and let all the strata, from the lowest to the highest beds of the section, be conformable. Then, by joining up the disrupted edges of

the beds in the manner indicated by the dotted lines, in conformity with the known normal curves deduced from accurately observed surface dips, it follows (granting their original continuity), that before the limestone became disjoined, its beds were arranged in the form of the uppermost curved line *b b*; and portions of these beds formerly resting above the present surface, *c c*, have by some means been removed.

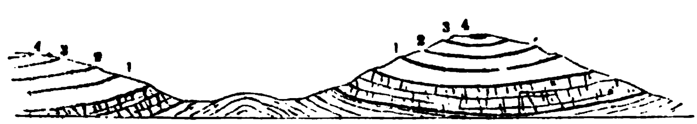
Fig. 2.



This is not the place on which to enter on a lengthened disquisition as to the proofs by which certain masses of rock, far apart, are taken for granted to be the same, but it may not be amiss to assist those unaccustomed to geological reasonings, slightly to touch on one or two of the more obvious evidences.

Let Fig. 2 represent a portion of a map of a country composed of old red sandstone, carboniferous limestone, and coal measures. The carboniferous limestone is seen throughout all its course to rest in the old red sandstone, and the coal measures, on the intermediate limestone. Let the curved lines 1, 2, 3, 4, be the outcrops of various beds of coal, traced along the surface, and some of them curving round on the promontory in the centre of the map. They are *seen* along all the surface to be the same continuously, and along the line of section *a a*, would (assuming an outline of ground, Fig. 3) present the following appearance.

Fig. 3.



In this instance certain beds are traced continuously along the surface, yet in the section drawn straight across the country these continuous beds seem to be completely disjoined. Carry the process which (Fig. 2) has partially disjoined some of the beds, a step further, at the neck of land *b b*, and the promontory becomes as it were an island. Yet the same section, *a a*, drawn across the country so transformed, would present exactly the same appearance as it does according to the first hypothesis. These outliers, as they are termed when such masses become disjoined, are familiar to every geologist. In the maps of South Wales and the adjacent counties lately completed by the geological survey of Great Britain, the Forest of Dean (an outlier of the great Glamorganshire and Monmouthshire coal field) forms a beautiful example of this isolation of part of a country (Pl. 4, fig. 2), and in the district now in process of completion, the great outlying patches of old red sandstone at Clun Forest, and near Knighton in Radnorshire, are equally striking. Nor would any one acquainted with the evidence, doubt the present continuity of the Glamorganshire and Pembrokeshire coal fields beneath the sea in Caermarthen Bay. Yet they are seemingly disjoined, without in reality being so; nor is it difficult to conceive with an altered relative level of sea and land, the very same causes that have *so far* disjoined them, carried on a little further, till

the Pembrokeshire coal field became in reality what to the uninitiated eye it may at present appear, an outlier of the larger carboniferous tracts of Glamorganshire.

Again, in certain given conditions of conformity in large formations, and where these formations have over great tracts been found to be generally constant, a skilful geologist will often, in examining a country, predicate with almost absolute certainty where such and such rocks will be found. He may have measured the general thicknesses of the larger formations, and be well acquainted with the varied appearances that their parts present to the eye. Let us suppose such a one walking along the line of section (Pl. 4, fig. 2), from the coal field of Monmouthshire to the Forest of Dean. Knowing at starting that he was near the bottom of the coal measures, and being well acquainted with the average thickness of the carboniferous limestone for miles around, he would soon, having passed its lower shales, begin to look for the dingy-coloured beds of the old red sandstone, and as he progressed eastwards, measuring the thickness of that great deposit, he would as he got towards 7,000 feet of vertical thickness, begin to look out for the Silurian rocks to the west of Usk. Finding that they rolled over in a great boss, he would again prepare for the old red sandstone, and generally surmounting the same beds through which he had already descended, (taking them *en masse*) he would experience no surprise, when he found the carboniferous limestone and coal measures caught on the summits of the Forest of Dean. And why is this the case, but that (possibly without being himself aware of it) his mind tacitly acknowledges that the outline he has traversed is but a ruin, and the Forest an outlying fragment of the great coal field he left, spared amid the general wreck.

Another branch of the subject, also already hinted at, is closely akin to the foregoing, and offers not less conclusive evidence of the same extensive removal of material. If, as in the accompanying diagram (Fig. 4),

Fig. 4.

a certain proportion of given masses of conformable strata be thrown on end, or nearly so, it is absurd to suppose that the beds composing it could each have ceased to be deposited at their present truncated edges, since such supposition would imply that during deposition each bed suddenly ceased at a given point, thus forming a nearly vertical wall of great height. This is impossible. Such instances are of frequent occurrence in South Wales, and are no where more remarkably developed

than on the south side of the Towy in Caermarthenshire, where, in the district extending from the east of Landovery to the neighbourhood of Caermarthen, the Silurian rocks and part of the old red sandstone, are thrown nearly on end through a depth of strata of from 6,000 to 9,000 feet in thickness. Various figures in Pl. 4 and 5 illustrate this point, and many more may be seen in the larger sheets of published sections on a scale of six inches to the mile. It is impossible then that such great deposits could have ceased suddenly, nor is it even probable that they should have thinned out within a very short distance of the outcrop of the beds. It thus becomes evident that a great portion of the strata has been removed from the existing surface, either before or after the disturbance that threw them into their present position. It will shortly be shown that this destruction of material occurred after disturbance. In applying these principles the utmost caution is requisite, nor can it be safely done without a complete consideration of all the circumstances attending the deposition of entire systems of strata over extended areas, including especially all the disturbances, great or small, to which they may have been subject both during and after deposition.

If we examine the bearing of this subject on South Wales and the adjacent counties on which the Geological Survey of Great Britain has lately been engaged, very remarkable results are obtained.

It is impossible to inspect any of the sections relating to this district now published, without being struck with the great amount of matter which they indicate has been removed from above the present surface. A few of the more striking of these sections have been reduced and adapted more immediately to illustrate the subject (Pl. 4 and 5), the darker coloured parts representing the outline of the county as it now exists, relatively to the level of the sea, the lighter tints of the same colours indicating the run of the strata beneath that level, and their supposed restoration above the existing land.

If we unite the edges of the strata in Section No. 1, Pl. 4, across the Woolhope district, in accordance with the dips of the outcropping beds, we obtain at the highest point an additional mass of matter reaching about 3,500 feet above the present surface. In the sections across the Malverns (Sheet 13*), the amount of added matter attains an additional height of from 4,000 to 5,000 feet. Only a small portion of the old red sandstone is included in either of these rude calculations, though there can be no reasonable doubt that more might safely have been added, the old red sandstone of these neighbourhoods attaining a measured vertical thickness of at least 7,000 feet of original deposition.

* Not engraved among the reductions, Plates 4 and 5.

If we restore the severed strata of old red sandstone and carboniferous limestone in section (Fig. 4, Pl. 4) from Glastonbury Tor across the Mendip Hills to the banks of the Severn, we obtain at the highest point above the Mendips, an additional mass of strata 4,000 feet in height, and in the district to the north near Bristol one of 5,000 feet. A glance at the geological map of Somersetshire (Sheet No. 19, or Plate 2) will show, that owing to the dome-shaped curve of the strata at the eastern end of the carboniferous limestone, near Winford, it is probable that these rocks rise close towards the surface between Beach and Dundry Hills, the overlying coal measures accommodating themselves to this curve, and the whole being concealed by unconformable beds of new red marl, lias, and oolite. The total thickness of the Bristol coal field amounts to 6,500 feet. If (as every evidence tends to show) it rises and falls with the limestone between the river Avon and the Mendips, then the same proofs that evince the destruction of so great a body of limestone from above the plateau of the Mendips and elsewhere in the neighbourhood, warrants the supposition, that the mass of coal measures south of the Avon, may have been carried in accordance with the dotted curves, across the Mendip range; and on such supposition, based on the present disposition of the carboniferous limestone of the country, depends the probable existence of coal-bearing strata beneath the alluvial flats of East Sedgemoor. Adding, therefore, to the height already given, the known thickness of these strata, we obtain an additional mass that has disappeared, of about 2,500 feet in thickness. Still, even this is but a fragment of the lower coal measures, which has survived the general wreck of many a tearing denudation, saved, like some other coal fields, from utter destruction, by the happy accident of the unexposed position into which it was partly thrown by disturbances subsequent to its deposition.

In the section across the South Welsh coal field, extending from the Bendrick rock over Cefn Merthyr, denudation, on the south, has taken place on the largest scale (Fig. 5, Plate 5). If we restore that part of the country lying between the Bendrick Rock and Garth Hill, we obtain for the component rocks at their highest point, a vertical mass of from 4,000 to 5,000 feet high. With the addition of the coal measures at Garth Hill, the mass would be increased by 4,000 vertical feet. Four thousand feet of coal measures could not utterly thin away within a few hundred yards, and, on the authority of Sir Henry De la Beche, it has been considered more than probable that a trifling portion of coal measures underlies the flat unconformable beds of new red sandstone and liás, between Mount Pleasant and Twyn Bwm Beggan. But further west, the coal measures gradually attain an increase of thickness above those included in this section, of not less than 4,000 feet, by the coming on of

beds higher in the series. It is, therefore, not unlikely that, including all the rocks from the old red sandstone upwards, 9,000 feet is not the greatest amount of vertical denudation which these rocks have suffered in the district between Bendrick Rock and Garth Hill. The same proofs suffice to show, that across the whole of the remainder of the section (Sheet 11, not given in the reduced plan), to the north crop of the carboniferous limestone near Allt Llwyd, the entire surface has been more or less reduced, occasionally, to the depth of several thousands of feet. In any section, drawn across any part of South Glamorganshire, similar phenomena would present themselves.

If we now turn to Pembrokeshire, we shall find that the same causes have been at work, on a scale equally grand. Indeed, from Pendine, on the borders of Caermarthenshire, to Cardigan, on the north, the violent contortions affecting all the older strata are no where more beautifully exhibited than on the sea-worn cliffs of Pembrokeshire. In some places, as in the section selected to illustrate the destruction of matter in Pembrokeshire (Pl. 5, fig 6), a restoration of the strata produces the most fantastic curves.

Many well-measured sections have shown that, generally, in South Wales, the coal measures, carboniferous limestone, and old red sandstone, each exhibit a tendency to thin out from south to north. This, and the gradual successive overlapping of the different formations, have been fully discussed in another part of this volume. But making every allowance for this declining thickness of old red sandstone and carboniferous limestone towards the north, we are yet forced to admit the removal of masses of strata, which, if restored, would rise, in the part of the country south of Rosemarket, from 3,000 to 6,000 feet above the existing land. (Plate 5, fig. 6).

Between Rosemarket and the coal measures north of that village, are two masses of trap, which would appear, from the position of the neighbouring strata, to have been protruded through lines of dislocation, caused perhaps by the same forces that so remarkably bent and fractured the strata. The confusion is here so great, that it is impossible to restore the strata denuded from the present surface. The whole country seems to have been cast down by two successive steps, the most northerly of which brings the uppermost bed of the coal measures of the district to the same level as the Silurian rocks, near Rosemarket. A gradual overlap of the coal measures brings that deposit in immediate superposition to the lower Silurian strata, near Haverfordwest. At the north-east angle of St. Bride's Bay, these measures are still 2,000 feet thick. Making all allowances for those slight unconformities that accompany the various overlappings of the superior strata in Caermarthenshire and Pembrokeshire (and they are so slight, that within

small districts they are quite imperceptible), we still obtain by restoring the coal measures only as far as Trefgarn rocks, an additional mass of matter removed from above the present surface, varying from 2,000 to 6,000 feet in vertical height. On the coast of St. Bride's Bay the coal measures are, as it were, dovetailed into the Silurian country by various faults; and, consequently, with this estimated thickness of 2,000 feet, close to where these rocks are bounded by two large faults, it is self-evident that the strata must have extended further both to the north and east, since we dare not assume so great a mass to have died suddenly away in any given direction. We are, therefore, clearly justified in presuming that the coal measures originally extended further both north and east than the parallel of Trefgarn rocks, though how far it is now impossible to say. (Geological Map, sheet 40.)

We might enlarge on the chances of these coal measures having surmounted the carboniferous limestone in the district between Haverfordwest and St. Govan's Head. By an extended examination of the South-Welsh, Gloucestershire, and Somersetshire coal fields, it would be easy to show that the hollow of the Bristol Channel is probably not destitute of coal, its existence there being based on reasonings connected with the chances above hinted at. We might thus add several thousand feet to the mass of strata already shown to have been destroyed in the southern part of this county. Enough, however, has been done to point out the magnitude of the masses removed, and in the absence of any *positive* proof, it is needless in this instance to speculate on probabilities however plausible.

The section (Pl. 4, fig. 3) sufficiently explains itself. It is only inserted to illustrate the point that the same operations have obtained, proceeding eastwards, through Pembrokeshire into Caermarthenshire, over whatever part of the country a section may chance to be drawn.

Between Caermarthen and Llandeilo the Silurian strata from the uppermost beds down to the higher Llandeilo flags attain a thickness varying from 5,000 to 7,000 feet. In the neighbourhood of Llandeilo, at Golden Grove, where good sections are visible, these rocks are seen to dip southerly at high angles, generally exceeding 60 degrees, till, on reaching the banks of the Towy, the lower beds roll over northwards in a series of contortions, in part well exhibited in Dynevor Park. This state of things continues far both to the west and east of Llandeilo. At Llangadoc, between Carreg-y-foelgam and Melin-fach, the Silurian rocks, with the lower part of the overlying old red sandstone still dip south-east at the same high angles. At Carreg-y-foelgam the lower Silurians suddenly bend over to the north-west, this bend being the beginning of a series of rolls which from thence are continued far across the country to the cliffs of Cardigan Bay. On good evidence, it has been considered

that the same sandstones and conglomerates which thrice crop out to the surface between Carreg-y-foelgam and the Towy, may be pronounced equivalent to the conglomerates and sandstones of Abermarles Park, and Llandsadwrn Fan. Reducing the curves which form the line of union of these beds to the lowest possible elevation, we still obtain an additional mass of removed strata across the vale of Towy of fully 2,000 feet. But it is absurd to suppose (Pl. 5, fig. 8), that 5,000 vertical feet of Silurian strata immediately north of Trichrug could suddenly have ceased to exist between Trichrug and the point where the strata first bend over to the north, since, in that case, the beds must have been deposited so as to form a wall 5,000 feet in height at one extreme end. And if we only restore them in accordance with the curves below for a very short distance, it gives a mass of matter that would, if restored, raise the land above the Vale of Towy to a height of 6,000 feet. If to this we add 5,000 feet of old red sandstone (measured between Trichrug and the Black Mountain), we attain matter equal to 10 or 11,000 vertical feet removed from the existing surface. We dare not assert that part of the carboniferous limestone and coal measures might not, with truth, be added to swell the magnitude of this mighty destruction of solid rocks. Supposing, however, that no part of them ever existed above the strata which, it is argued, once rested on the rocks now occupying the Vale of Towy and the country on its northern banks, and allowing that the upper Silurian and old red sandstone strata may have thinned away to half their measured thickness before reaching the point now occupied by Llansadwrn Fan, we still obtain many thousand feet of strata, now no more, once spreading over an uncertain distance towards that which is now the coast of Cardigan Bay.

It thus becomes evident that the same arguments, resting on the high angular position of the strata, equally apply further west from hence, towards Llandeilo and Caermarthen.

The same reasonings may also readily be applied to the next section, north-east of Llandovery, from Mynydd Bwlch-y-groes to Cardigan Bay near Aberaeron (Pl. 5, fig. 7), part of which is here reduced from Pl. 4 of the sections of the Geological Survey.

It is worthy of remark, however, that in this instance the upper beds of the Silurian series, if restored, would rise about 12,000 feet into the air, or nearly double the height of the same strata only eight miles, to the S.W., at Llangadoc. The Silurian rocks would indeed, in such a case, occupy a more elevated position than the highest beds of the old red sandstone, if restored to the Llangadoc section. This is owing to the same great anticlinal roll having, in the present instance, brought to the surface strata several thousand feet deeper in the

series than any that appear in the neighbourhood of Llangadoc. But, as in the cases already instanced, it is evident from the high angle of the old red sandstone at Mynydd Bwlch-y-groes, that its deep deposits could not originally have come suddenly to an end in that locality; and thus, without reference to any higher formations, we are forced to admit the necessity of adding to the enormous amount of Silurian matter removed, at least part of the old red sandstone, verging, in this neighbourhood, on 6000 feet of vertical thickness.

In the Section, sheets Nos. 5 and 6* of the large plates, on a scale of six inches to the mile, a reduction of which is not given, the same deductions are very apparent. In this section (where it is impossible in many parts of the line to dispute the original continuity of the beds), the increased amount of matter superimposed on the present curved strata would vary from 4,000 to 6,000 vertical feet, and, by fair inference, sometimes to nearly double that amount.

One of the most evident and striking instances of the removal of a vast body of matter from the existing surface, is shown (Plate 4, fig. 2), in the section from Cefn Crib, in Monmouthshire, across the Forest of Dean, to the banks of the Severn. In this section all the rocks are, as far as we know, quite conformable. In its restoration no allowance is made for the disappearance, by denudation, of any part of the coal measures from above that which still remains on the tops of Cefn Crib and Dean Forest; and be it remembered, that Cefn Crib forms part of a coal field which attains a total thickness of many thousands of feet, and that Dean Forest is but an outlier of that great coal field. There is, therefore, scarcely room for a doubt that to a certain extent such denudation must have taken place. This section has been constructed with the utmost care on the usual scale of six inches to a mile. Taking the measured thickness of the strata at the lowest possible estimate, and restoring the beds in accordance with observed surface dips, we obtain curves exhibiting elevations above, and depressions beneath the level of the sea, of nearly equal value. The Silurian rocks diving beneath the surface at Usk, are considered to underlie the old red sandstone throughout the whole extent of the section, since they again rise at May Hill, and at Tite's Point, on the Severn, not far from the Forest. Indeed, through the great tract of old red sandstone between the Welsh Silurians and the Severn, the latter rocks rise to the surface wherever the rolls of the strata will allow of their appearance, so that they doubtless underlie all that great tract, and probably much of the newer unconformable strata still further east, of which the new red sandstone forms the basis. We are thus justified in carrying the Silurian

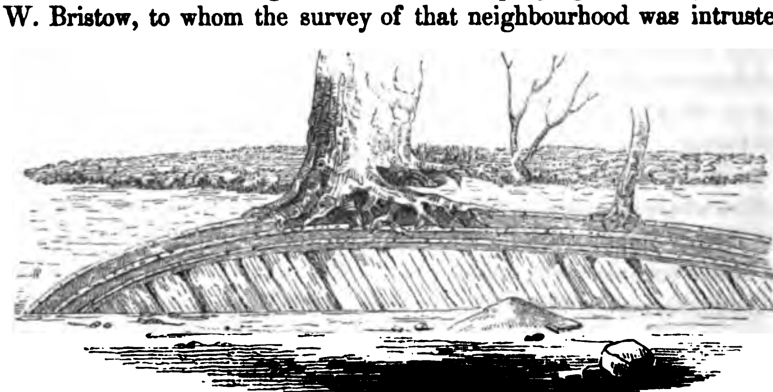
* Drawn from the Black Mountain range across Carneddau, in the neighbourhood of Builth, Radnorshire, to the coast of Cardigan Bay, near Aberystwyth.

rocks beneath the Forest of Dean. In this manner, by taking in the whole subject of the strata of the section at one glance, it is evident that it is as easy to conceive the higher beds carried by the same cause so many thousand feet into the air, as it is to believe the lower beds diving to an equal depth beneath the level of the sea. A little on the east of the Forest, this increased elevation amounts to 6000 feet; and from the Forest, which averages in height about 900 feet above the sea, we have a gradual rise, for seventeen miles westerly, till it attains the height of 10,000 feet above the centre of the anticlinal axis near Usk. All this restored matter has been removed from above the present outline of country.

The same order of reasoning would apply to all the country lying between these sections and Cardigan Bay, more especially to the wide-spreading anticlinal axis of the Vale of Teifi. It might also readily be applied to the outliers of old red sandstone near Kington and Knighton, showing their original connexion with the main mass of that formation; but enough has been said to indicate the universality of this great denuding process over the older rocks of Wales and its neighbourhood.

Let us now endeavour to analyse the causes that have produced these great effects. To do this, it will be necessary rapidly to glance at some of the more leading conditions that obtained during the deposition of the rocks so remarkably denuded, in so far as such depositions may have been affected by contemporary disturbances.

The partial unconformity of the Silurian strata of North Wales and the neighbouring eastern counties is well known. These unconformities distinctly indicate the occurrence of occasional disturbances in the sea bottom of the time when the rocks were being formed. Such partial movements extended throughout the deposition of the entire mass of strata, a beautiful example of which, in the lower beds, may be seen on a small scale near Knighton, in the accompanying sketch by Mr. H. W. Bristow, to whom the survey of that neighbourhood was intrusted.



They were also continued during the deposition of the old red sandstone and carboniferous limestone; and it is evident that, from the time of their first commencement, they were attended with partial denudation of the disturbed strata, from the circumstance that certain beds often rest on the upturned disrupted edges of beds, perhaps immediately underlying them in the geological series. But that in this country the movements of the period were not on a great scale, is attested by the fact, that the unconformable strata do not rest on beds so intensely and widely contorted as we find, at a subsequent epoch, the rocks in South Wales, to be from the top of the coal measures downwards. Indeed, as regards the disturbances during the Silurian period, they do not appear to have exercised the smallest influence on the more southern deposits, since the conformity of the entire series seems to be perfect throughout. Whatever may have occurred during the progress of the formation of the old red sandstone and carboniferous limestone on the E. and N. E., the movements of the time seem to have been almost equally powerless in Southern Wales, the smallest possible degree of unconformity between Silurian, old red sandstone and carboniferous limestone being evinced by the exceedingly gradual overlappings of the various strata proceeding westward from Caermarthenshire to the coast of St. Bride's Bay; and further east between Hay and the vicinity of Llandeilo, by a similar westerly overlap, the upper sandstones of the old red series gradually creeping over 2,000 feet of its own lower marls.

In the eastern part of the great Welsh Silurian region before the commencement of the deposition of the coal measures, a disturbance of more marked intensity than those that preceded it took place. This was apparently one of the districts where producing more forcible effects, its intensity died away to the west, till in the South-Welsh counties it was comparatively unfelt. The proof of this may be distinctly seen near Coalbrook Dale and Shrewsbury, where the Silurian strata are highly distorted, whereas the overlying unconformable coal measures rest in comparative quiet.

That this movement was in these eastern tracts attended with considerable elevation, is evident from the very apparent denudation of the lower unconformable strata by the waters of the coal measure period. And though comparatively faint and unimportant in the western districts, the same upheaval of strata may probably have gently elevated the Pembrokeshire and Caermarthenshire central districts above the surrounding water, thus forming part of the coast of that water, the waves of which washed a country but little elevated above its margin, with long flat marshy plains, such as might be favourable for the growth of the plants forming so important a feature in the carboniferous strata. It would indeed even appear that this gentle elevation of the western

districts may have been of earlier date, extending far back into the Silurian epoch, and at the same time, that at all periods it was so small and the seaward slopes so gradual (arising from the strata composing the land being as it were barely lifted above the waves), that the new rocks formed on its coasts can scarcely be discovered to differ in angle from those on which they were deposited.

Let *a a* (Fig. 6) be the land formed by certain strata, of which *a′* is the continuation beneath the waters, then the new strata *b* formed above *a′*, would if the whole were afterwards contorted together, seem to be conformable with the entire length of the strata *a a a′*.

In the case of any sea playing around flat coasts of this description, it is clear that its action is not such as to produce destruction or denudation of the land, but rather to preserve it for a time for further waste, by the addition of fine sediment derived from other lands, which as the tides flow and ebb is often partially carried into the interior as blown sand.

This idea of land in the north gains probability from the fact that the old red sandstone, carboniferous limestone and coal measures of South Wales all have a tendency to thin out from south and north, as if one of their landward limits had been in that direction. But if such were the case, it is evident that in the sea bottoms of the period there must have been periodical or perhaps very gradual and gentle depressions around the coasts, slowly submerging part of the low lying lands. This is distinctly evidenced by the overlappings of the several formations gradually covering up each other, till at length on the coast of St. Bride's Bay the coal measures rest directly on the lower Silurian strata. Let *s s*, Fig. 7, be the level of the sea, and *a a a′* certain Silurian strata, part of which *a a* are slightly raised above the waters, and let *b* be the old red sandstone in process of deposition round its coasts. Depress the entire mass and the carboniferous limestone *c* might creep across the sandstone, resting in part directly on the Silurian rocks. Carry on the same operation still further, and the coal measures might occupy a similar position. (Fig 8.)

Let all these be heaved up *en masse* over a large tract of country, and after denudation they might have the very appearance now presented by the same strata in Pembrokeshire, where there are unconformities so slight as to be almost imperceptible. So trifling in fact is the difference of angle, that an examination of any limited tract of the whole district would not lead to any suspicion of the existence of such difference.

It should be remembered, however, that in examining these overlaps as they exist on the surface, we do not look upon the original edges of the different formations, the margins of which as they originally lay

Fig. 6.

Fig. 7.

Fig. 8.

s s, the level of the sea; *a a'*, Silurian rocks; *b*, old red sandstone; *c*, carboniferous limestone; *d*, coal measures.

before violent disturbance, must formerly have extended much further towards the central district of the Silurian region of South Wales. We are, on the contrary, dealing with them after contortion and denudation, their present northern edges being parts of the strata

more or less removed from their original margins. This is strikingly exemplified in the coal measures of St. Bride's Bay, which at their northern extremity still retain a thickness of 2,000 feet.

If the fact of the thinning out to the north of the various formations above mentioned, be considered as evidence of the existence of a landward boundary in that direction, it affords additional proof that the first existence of that land originated in a modification of the same disturbances that during the Silurian period, more strongly affected North Wales and the Shropshire Districts; and the subsequent overlaps of the South-Welsh strata in that case may have arisen in a modified continuation of these disturbances which while they more largely and variously affected the northern districts, were only felt in the south by gentle depressions, slowly bringing by little and little more of the sloping shores within the margin of the sea (see Figs. 6, 7, 8). Mark the inference to be drawn from this. In the north we know that before the deposition of the coal measures the strata beneath were partially upheaved and contorted, and the land thus formed was washed by the coal measure waters. And if, as has been inferred, this land more quietly upheaved be extended southward and westward to Pembrokeshire, we obtain a country flanked all round on the east and south by waters in which slowly, and at intervals, accumulated the beds of the coal measures. One denuded edge of these accumulations now forms part of the counties of Pembroke, Caermarthen, Glamorgan and Monmouth, and is elsewhere exhibited in the Forest of Dean, the narrow strips of coal measures north of May Hill in Gloucestershire, the Clee Hills (outliers of the Forest of Wyre and Coalbrook Dale), the coal fields south and west of Shrewsbury, and that of Oswestry, Wrexham, and Mold. All these are but fragments of one great original coal field, once mantling round North Wales and the older rocks west of the Severn and north of Bristol Channel.*

And now briefly glancing at the disturbances attending the deposition of the Welsh rocks, it has been found that though in the north some considerable movements of the strata occurred previous to the close of the coal measure deposits, yet that along the range of South Wales these commotions were almost unfelt, the whole series of rocks from the lowest Silurian of Caermarthenshire and Pembrokeshire to the highest coal measures of Glamorganshire, resting in regular and (almost perfectly) conformable sequence. But at the close of the coal measure period a catastrophe occurred by far exceeding in intensity any of the

* The Author recently had his views on this subject confirmed by Mr. D. H. Williams (lately of the Geological Survey of Great Britain, now appointed to the superintendence of the Geological Survey of the coal fields of India by the honourable Board), who, in his official capacity, has had the most perfect opportunity of forming a correct opinion on the subject.

previous disturbances, and of the forces producing this movement South Wales largely felt the intensity. These forces heaved the entire mass of strata high above the surface of the waters, violently disrupting and bending the thick masses of Silurian rock, old red sandstone, carboniferous limestone and coal measures, now into long sweeping curves and now into rapid and fantastic contortions of every conceivable size. Further north this disturbance exercised a milder influence, the evidence of which may be found in the quiet disposition of the Shropshire coal fields, when compared with the highly contorted coal measures of Pembrokeshire, and the western parts of the counties of Caermarthen and Glamorgan. These movements doubtless extended into districts far removed from Wales and the western counties, but this is not our present province.

It does not follow because we find the new red sandstone resting directly on the upturned strata, that therefore this exertion of power took place precisely at the period when the progressive formation of our coal measures generally ceased to be carried on, and the new red sandstone times began. Such rapid transitions may be sudden locally, but they are not so universally. Further north there is said to be sometimes a gradual passage from coal measures to new red sandstone, and such might well be the case in comparatively undisturbed districts, or where, though disturbed *en masse*, certain portions of the strata retained a position approximating to their original horizontality.

In the district, however, of South Wales and the neighbourhood more immediately under review, the intensity of the disturbing action produced results of corresponding magnitude, and when the mighty mass of materials from Silurian rocks to uppermost coal measures inclusive had been rent and twisted and heaved high into the air, a set of conditions must have been produced, so different from those that previously obtained, that it would be rash to expect the continuation of the formation of coal measures under such altered circumstances, when the new disposition of land and water had so completely altered the height of the country, the depth of the seas, and thus, perhaps, materially influenced the climate.

Respecting the contortions of the strata already so frequently referred to, it is not essential to the argument to account for the absolute means by which they may have been produced. It is sufficient that the contortions exist.

A minute acquaintance with the physical relations of the country shows that the rolls of the strata form great systems of anticlinals, synclinals, domes and oblong dome-shaped curvatures; the smaller contortions forming but minute portions of these, having in fact, as has been remarked by Captain James, the same relation to the great rolls of the

strata, that the ripple on the surface of the waves bears to the heavy ocean swell. Such great and universal effects could not have arisen from the operation of petty detached forces acting here and there at various times on numerous points of the surface. The extent and *unity* of the results speak to the contrary. There are indeed in South Wales evidences of disturbances of strata previous to this period; such disturbances in early Silurian times being probably accompanied by the occasional protrusion of igneous matter; but these igneous rocks themselves, and the strata with which they are associated, have all been equally affected by the last great commotion previously noticed.

There is every reason to believe that this commotion, wherever it was felt, acted on a nearly uniform average thickness of rock, if we consider it in reference to the whole crust of the earth so affected. The entire thickness of the *strata known* to be so affected must be variously estimated according to the district measured.

The Silurian rocks are not less than from	8,000 to 12,000	feet thick,
The old red sandstone . .	4,000 to 7,000	„
The carboniferous limestone . .	100 to 2,000	„
The coal measures . . .	8,000 to 12,000	„
	20,100 to 33,000	„

It is not pretended, indeed we have attempted to show, that such an aggregate thickness of these rocks never did obtain at any part of the area between Cardigan Bay and Bristol Channel, to the north of the coal measure boundary. It is, however, impossible to say what depth all the strata diving under the coal measures may attain.

Quite independently, however, of these considerations, when we take into account the inconceivable amount of time necessary to form so great a thickness of such various deposits, in which numerous species and genera, race upon race, lived, died, and were followed by others in many successions,—a period of time in which creation gradually passed from phase to phase till, in the far removed extremities, each is all unlike the other,—when this is taken into account, it cannot be supposed that such a vast thickness of rocks, so slowly deposited, remained unconsolidated till after the great event that so violently altered their disposition. The limestone itself offers evidence to the contrary. If we consider also many of the tertiary deposits in Europe and in Asia,* some of them in point of *geological time* but a small way separated from the present era, they are yet often found to be consolidated into hard and stubborn rock. Much more, then, is there reason to believe that these earlier rocks,

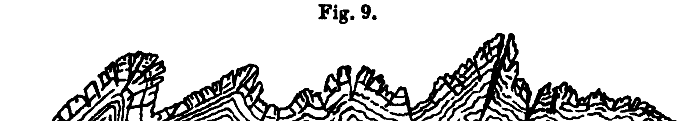
* Paris basin, Grecian Archipelago, Himalaya mountains, &c.

belonging to eras much further apart, must have been consolidating and consolidated, even while the very process of formation was going on.

When we consider the amount of resistance to lateral pressure, or any other force, that would be offered by so solid a mass, it seems still further impossible that any such large general result as we find indicated by the great rolls, could have obtained from the conflicting action of petty forces working at various times, in whatever manner these forces may be supposed to have been applied. The mighty catastrophe that closed the coal measure period of this old land must, therefore, have been attended by an intensity of disturbing power commensurate to the grandeur of the effect produced on the masses of contorted strata. That the movement was not caused by a number of detached efforts is further evident from the almost absolute conformity of all the rocks in South Wales, subject only to the variation of the quiet overlaps of Pembrokeshire, &c., already dwelt upon; overlaps, it has been shown, unaccompanied by violent disturbance in the places where they occur, but rather resulting from the fading away of the effects of greater commotions in distant districts. Furthermore, had the contortion of the South-Welsh strata been produced by many strong distinct efforts extending through a great lapse of time, we should expect to find evidences of unconformity in the contorted strata themselves, as we observe in the case of the earlier disturbances further north. But no unconformities of this nature exist; and this, independently of the unity of the system of rolls, affords a strong presumption, if not conclusive evidence, that the contortion of the strata was the result of one gigantic effort of contraction, or of a series of efforts so closely approximating, that, in point of geological time, they may be considered as one: for the sea never spares, and so surely as the new lands arose, unconformable stratification, the result of new denudations, must have ensued.

Respecting the effects produced on the rocks subjected to this great catastrophe, it is unnecessary here to enlarge. Flexures so large and sudden, must have originated slidings of the bent strata on each other, accompanied by faults and fissures gaping widely on the surface. The cracks we now trace convey but a faint idea of the rent and fissured aspect of the ancient surface immediately after this great catastrophe. The newly bent surface beds doubtless exhibited a shivered aspect analagous to that represented in Fig. 9; and the fact,

Fig. 9.



that the curved strata now exposed present, as a general rule, no such intensely fractured surfaces, leads to the conclusion, that great as was the lateral pressure necessarily exerted to form such curves, the immense superincumbent weight of strata then existing, *but since removed by denudation*, was sufficient, by pressure alone, to save the lower beds (those we now see) from the shattering influence to which the surface was subjected. The largest of these displacements, however great it may appear when compared with our conventional measurements, is but trifling when viewed in connexion with the greater phenomena, of which they form a part, scarcely interfering with the regular sweep of the wider curves of the shrunken strata.

Viewing the rocks beneath the new red sandstone of our district on the largest scale,—when we consider the manner of accumulation of the various deposits, and the conditions under which they existed at the close of the coal measures, it seems probable that in the rocks themselves there is sufficient internal evidence, that the general tendency of the disturbance by whatever cause produced, was to effect an upward movement of the general mass. But we are not cast upon such evidence to prove the point.

No sooner was this new land raised above the waters, than the sea and the atmosphere began their work of denudation, the result of which we now partly see in the deposits of new red sandstone encircling the underlying disturbed strata of Wales and the neighbouring counties. It has been shown by Sir Henry De la Beche, that the magnesian conglomerates encircling the Mendip Hills, in the neighbourhood of Bristol, on the southern skirts of Glamorganshire, and elsewhere, do not universally underlie the entire formation of new red sandstone as an independent system of rocks of a given age, but in fact are of all ages appertaining to that formation as known in these counties, and once formed part of the shingly beaches of the new red sandstone sea on the margin of the coast of the recently waterworn land. This may be best seen by an inspection of the larger published sections on the six-inch scale, where such minutiæ can be conveniently depicted.* But this beach gives evidence of a kind even more remarkable than the above, for it furnishes us with data on which roughly to calculate the approximate general height of the land above the sea of the period, assuming the level of the sea to be in general terms constant, and that of the land alone to be fluctuating. Remarkable as it may appear at first sight, this height is to be found in sections, in which the original curves of the severed strata are restored in the manner indicated by the drawings (Pl. 4 and 5). At the same time, let it be remembered, that even now we have

* See also the figures, page 242.

mountain chains attaining far greater elevations than the most lofty of these restorations, some of these ranges being in great part composed of highly disturbed strata, of comparatively small geological antiquity.

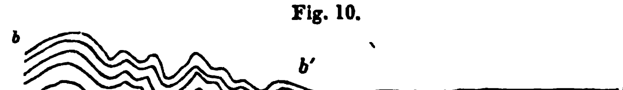
It is well known, that we have but a very imperfect development of the new red sandstone series in some parts of England, especially of its lower members. Were there, then, ever any deposits surrounding these old coasts corresponding to the missing members? This question it is impossible definitely to answer, and yet there is some presumptive evidence. Wherever there is a coast denudation, the construction of new strata is constantly progressing. It is improbable that the land could have risen above the waters without the formation of new strata around its coasts, and far or near wherever the seas of these old lands flowed, there would have been deposits of some kind equivalent to the larger development elsewhere of the missing members. Either, therefore, parts of our higher Welsh coal measures are equivalent to the missing strata (an improbable hypothesis), or these strata after formation were again destroyed, or they are concealed by overlapping upper beds of new red sandstone, which still resting as it were in a comparatively undisturbed basin, may conceal the missing members in its hidden hollows. This last hypothesis seems to be the truth, agreeing as it does with the fact, that the upper beds, especially the marls, gradually overlap the lower sandstones and conglomerates of the new red series, progressing from north to south, till in Gloucestershire, Herefordshire, Glamorganshire, and Somersetshire, the marls rest directly on the underlying unconformable strata. This then shows a tendency to a certain amount of contemporary depression of coast and sea bottom on the south to admit of an overlap during the formation of these deposits; so that, supposing the older beds of the new red series to be concealed somewhat to the east of the margin of that formation where it now rests on the upheaved strata, it would follow that, during the deposition of these elder members, the land washed by the waters of the new red sea, was once even somewhat more lofty, assuming the average level of the magnesian conglomerates to have marked the relative levels of sea and land of the later epoch.

There is every probability, therefore, that this older land was destroyed and denuded back by the elder sea, and a gradual depression ensuing southward, permitted the further encroachment of the later sea, so that its deposits *overlap* the lower members of the same series, and rest directly on the ancient contorted strata.

Fig. 10 will best explain this subject. Let the strata *a d* represent the older disturbed rocks, part of which from *b* to *b′* are in their original undenuded and contorted condition. The strata between *b′ d* have been

partially subjected to the ravages of a sea, which, cutting them backwards, and breaking the continuity of the contortions, has with the debris thus obtained formed the unconformable deposits *e*. A subsequent slight depression admits still further encroachments, so that we have the later beds *f* resting directly on *b*′, still further denuding them and entirely concealing the rocks *e*. Such combinations occurred on the ancient coasts now under consideration.

Fig. 10.



Looking at the entire subject, as it affects the geology of the western districts, we have thus seen that the north, east, and south of Wales, with part of the country immediately adjoining, formed a tract of land the coasts of which were ravaged by the breakers of a sea constantly grinding up the cliffs of old red sandstone, carboniferous limestone, and coal measures, of that which now form parts of the counties of Hereford, Gloucester, Monmouth, Glamorgan, and Somerset. It is even not improbable, that, besides sweeping the entire eastern and southern coasts of these ancient lands, it may have extended through the Bristol Channel, and rounding the northern coast of Wales, have washed the shores of a land in parts by far more lofty than its highest existing elevations.

During the new red and liassic epochs the waste of matter on the coast of their seas was on a great and extended scale. Of this truth we have evidence in the superficial extent and thickness of these formations themselves, the obvious inference being that the matter of which they are composed was mostly derived from the land around which the waters played. We have, however, other and more direct evidence when we consider the present disposition of these rocks, more especially of the new red sandstone, resting as it does immediately on the upturned and *denuded* edges of the older strata. In section No. 4, Pl. 4, it appears that a mass of limestone, &c., once existing above great part of the Mendip Hills to an extent of at least 6,000 feet high, had been removed by the denuding agency of the new red sea, or possibly by that sea and the earliest liassic waters, since we find the lower beds of the lias resting horizontally on the upturned waterworn edges of the older rocks that now form the flattened summit of the range. The same inference may be legitimately drawn with reference to all the remainder of the anciently disturbed rocks of the section from thence to the Severn. A similar work of destruction and reproduction of strata was in this neighbourhood carried on by succeeding seas, as strikingly evinced in the unconformable position of the oolitic rocks resting on the

denuded edges of the carboniferous limestone. The restoration of Section No. 5, Pl. 5, across the southern part of Glamorganshire, shows that the new red sea had denuded northwards from eight to nine miles of land between the Bendrick Rock and Llwynau-du, varying when entire from 4,000 to 9,000 feet in height. No. 2, Pl. 4, in that part of the section tó the east of the Forest of Dean, demonstrates similar destruction of coast by the same sea, and indeed it would be impossible in the whole of South Wales and South-Western England, to construct and restore any section extending from the older strata into the new red sandstone and lias, without exhibiting the same or similar phenomena. If we take an ancient line of coast of about 50 miles in length, from Swansea Bay towards the Malverns, and suppose an average denudation of 3,000 feet of strata for six miles inland, an average probably considerably under the mark, we should obtain a sufficiency of matter with the wrecks of which to reconstruct horizontal strata 500 feet thick over an area of 50 miles long by 36 in breadth; or, in other words, from an area of 300 square miles *above the waters*, we obtain by denudation a mass of new strata 500 feet thick over an area of 1,800 square miles.

Taking all these things into account, it is plain the quantity of matter destroyed by these ancient seas is more than sufficient for the formation of the deposits we know to have been formed in them; and if to this we add the more than probable hypothesis, that far to the eastward, shrouded beneath the overlapping strata of new red sandstone, lias, and oolites are concealed great tracts of abraded rocks, there arises no difficulty to conceive from whence materials were derived to form the overlying beds.

Throughout the period occupied by the deposition of the new red sandstone and lias, with various oscillations of level, it is yet evident that the general tendency was one of depression. This is proved partly by the upper new red marls gradually overlapping the underlying sandstones of the same series, and again by the position of the lias, occupying as it frequently does higher levels than much of the new red rocks, sometimes indeed resting directly on the shingly beaches of that sea (magnesian conglomerates), and not unfrequently, as in Glamorganshire, encroaching still further on the line of coast that bounded the preceding deposits. At a later period, however, it can be shown that the general tendency of the western land was for a lengthened time one of elevation, the successive oölitic deposits gradually accumulating in a diminishing area.* The new red and lias formations adjoining the ancient coasts

* See Sir H. J. De la Beche's Memoir on the Formation of the Rocks in South Wales and South-Western England, p. 285–295, and the Sections of the Geological Survey of Great Britain, Nos. 15 and 16, relating to Somerset and Gloucestershire.

were thus gradually raised above the waters, so that the later oolitic seas never reached the old red sandstone and carboniferous coast of the tract to the north of Bristol Channel, and west of the Severn. Indeed it cannot admit of doubt that in Somersetshire part of the lower oolites were already above water, while the upper portions were in progress of formation. Furthermore, the existence of the estuary and freshwater deposits of the Wealden in the east, give additional confirmation to these views, showing that towards the close of the oolitic period great tracts of dry land existed to the east of South Wales and Devonshire, since without such land there could have been no freshwater depositions, and without freshwater no estuary.

Subsequent to this time there was a period of depression. It has been shown by Professor E. Forbes and Captain Ibbetson that after the deposition of the uppermost Wealden strata, there was a sudden sinking of the district to the depth of several fathoms, converting by change of level the shallow estuary into comparatively deep sea.* They also show that much of the chalk was a deep sea deposit, founding their reasonings on the fossil evidence contained in the rocks themselves.† There were therefore in progress from time to time during the cretaceous era depressions of considerable magnitude, a fact abundantly proved besides by the overlappings of various members of the chalk stealing westwards and northwards across its own lower strata, and resting on scarcely disturbed beds of various subdivisions of oolite lias and new red sandstone. Finally, there exists an outlier of upper greensand near Bideford, in North-Western Devonshire, and it is considered almost certain by Sir Henry De la Beche that one or more members of the chalk may have spread from Dorsetshire over great part of that county, when Dartmoor rose beside the waters of the cretaceous sea. Whether or not the cretaceous sea ever reached the older strata of Glamorganshire and Monmouthshire may, however, admit of doubt, chalk flints having alone been observed by Mr. Ormerod of Manchester on the right bank of the Severn, near the mouth of the Wye. There is not, however, any proof that it ever reached the old coasts of Herefordshire, and indeed, judging by levels and the entire physical structure of the country, if the cretaceous seas affected these coasts at all, they never penetrated, so to speak, into the interior of our ancient Wales.

It is much more probable, that, for the greater part, the western margin of the cretaceous deposits rested upon the gently sloping coasts formed by the partially upheaved oolites or lias that mantle unconformably around the more anciently disturbed strata.

After the deposition of the chalk there was a new uplifting of the area,

* Journal of the Geological Society, vol. i. p. 192.

† Reports of the British Association, 1844, p. 44.

accompanied by partial denudation of the rising strata. A geological interval certainly elapsed between the completion of our chalk strata and the formation of the London clay. To obtain these latter beds in the position in which they now exist (the intermediate strata between the chalk and these clays being absent), we must either admit another depression of the land (chalk forming part of that land), or else that without a depression the sea wasted the chalk westwards. Into the area thus formed poured the drainage of the chalk country immediately around, and of the distant and more ancient formations on the north and west, now partially surrounding the London clay. At a later period denudations, shortly to be noticed, made great alterations on the disposition of the strata lying between the chalk hills and the Severn, wasting them backwards, and lowering the level of the country, and thus destroying the gradual eastern slope of the rocks above the coast.

Let us now shortly consider the physical structure of the great undenuded land of South Wales and its neighbourhood, during the long periods which elapsed between the new red sandstone era and these comparatively latter times.

If the previous reasonings be well founded, it has been shown that the disturbances affecting the older strata from the Silurian rocks to the coal measures inclusive, decreased in intensity in the south, so that while in North Wales the older strata by violent upheaval above the water had been frequently exposed to denudation, in the south these earlier disturbances became so little felt, that the rocks in the more central parts of the country (in Carmarthenshire, Cardiganshire, Pembrokeshire, &c.) were but gently heaved above the level of the sea.

These early lands formed successive lines of coast, to the accumulating deposits of old red sandstone, carboniferous limestone, and coal measures.

But the coast lines were further north and west than the existing north and west margins of these formations. This is shown by the manner of their denudation, as exhibited in their present disposition.

Again, the slight elevation of the southern land is proved by the almost perfect conformity of all the older formations, from the coal measure downwards, no unconformity being apparent except in great overlaps of the old red sandstone, carboniferous limestone, and coal measures which might well be occasioned by an imperceptible difference of angle. It is further shown by the absence of denudation where the various deposits rest on each other; for on flat coasts destitute of cliffs, there is little or no denudation.

At the close then of this period of comparative quiet these rocks were arranged somewhat exhibited in an exaggerated manner, in diagram No. 11.

But now there occurred that great catastrophe, accompanied by vast upheaval and contortion of all these masses of strata, which, by altering all existing local arangements terminated the conditions favourable and necessary to the continuance of coal measures, and beside which all previous convulsions of the rocks of the district were comparatively insignificant.* Then under a different economy in this part of the world the waves ravaging the coasts thus formed, and aided by the rivers of these new lands, deposited in the surrounding sea that series of unconformable formations, whose beginning was the new red sandstone; and from the margin of these seas rose a land, great part of which attained a mountain elevation of no ordinary magnitude.

Fig. 11.

a a, the level of the sea; 1, Silurian; 2, Old Red Sandstone; 3, carboniferous limestone; 4, coal measures.

In such a land there may have been every variety of climate, from the fiery heat of our present tropics to the cold of more northern climes. In latitude 0°, the line of perpetual congelation is about 15,207 feet above the level of the sea. In the latitude of South Wales, it would be probably about 5,600 feet high. If the climate of our latitudes, when the coasts were washed by the new red and liassic seas, were tropical, as is generally supposed, still on the heights indicated in the restored sections we have ample space for tropical and temperate zones, each probably abounding in its own appropriate forms of life. And here, in connexion with this subject, it may be remarked, that in Mr. Brodie's recent work, 'A History of the Fossil Insects in the Secondary Rocks of England,' it has been stated "that, *with certain exceptions*, the minute size of the great mass of the insect remains seems to indicate a cold, or at all events a temperate, climate." This appears to be directly at variance with the other fossil evidence, all of which has been considered by naturalists to denote that the animals whose remains are preserved were inhabitants of tropical regions. In the seas surrounding such a land, however, it may be that such apparent discrepancies were not incompatible. During Professor E. Forbes' dredging expeditions, in the seas off the coast of Lycia, he has remarked that, during the rainy season, the surface of the water was often partially covered with quan-

* This disturbance is treated of only as it affected the southern lands described in this paper, reserving to a future period the relation of other districts to this, as regards the phenomena attending their disturbance and denudation.

tities of dead insects, washed into the sea from the neighbouring land. By far the greater number of these insects were not derived from the hot low coast territories, but were borne to the sea from the more distant and lofty mountain lands* by sudden floods, which are then of frequent occurrence. They also, in accordance with the elevated regions from whence they came, bore the characters of temperate and cold climates; and it may be more than probable that the insect remains, described by Mr. Brodie, were washed from the mountain country we have described into the surrounding seas, and there entombed amid creatures of a tropical character. The rough usage they must have met with in such a descent, may also perhaps serve to account for their fragmentary condition.

It has formerly been attempted to be shown, that after the partial quiet elevation of the new red and liassic deposits formed in the seas that first surrounded this Alpine land, its elevations remained unabraded by aught save atmospheric influences till a comparatively late period, or in other words, that from the upheaval of the lias till the close of the London clay its heights were not subjected to the degrading agency of the sea. None of the newer uncomformable formations between this and the new red sandstone period, appear ever to have had an existence in the interior of Wales, and consequently, the low levels, constituting its existing valleys, are the result of denudations of later date. It follows then, that this lofty land, and much besides of the unconformable deposits mantling round its outskirts, have been swept away between the earlier tertiary epochs and the present time.

By reference to the six-inch sections (Plates 4, 5, and 6), it will be seen that the surface of the country they traverse, is often covered with drift from the present coast to the height of 1800 feet above that level. This drift more or less covers the greater part of Wales and the adjacent counties; and in some places, as in the country near Kington, is not less than 84 feet deep.† In South Wales it is almost entirely composed of the debris of the neighbouring rocks.‡ On the high grounds it may be said to be so almost exclusively.§

A careful examination of this deposit shows that it does not overspread the surface in confused masses, like a scattered heap of miscellaneous rubbish, but that it is composed of wide-spreading strata; often, con-

* Mountains on the coast of Asia Minor from 7,000 to 10,000 feet in height.

† I only notice this drift as it relates to the country under consideration. It has, of course, a much more extensive range.

‡ There is one striking exception on the coast of Cardigan Bay, at Aberystwyth, where on the beach are vast varieties of transported pebbles, the parent localities of which are somewhat problematical.

§ We except a few scattered boulders of granite and greenstone borne from a distance.

sisting of massive beds of gravel, of sand, small angular slaty fragments, clay, and pebbles, and layers of fine clay,—all such as frequently occur in shallow water, narrow arms of the sea, and in littoral deposits. Examples are common in every valley, among which may be instanced, those of the Wye (above Hereford), the Towy, the Cothi, the Teifi. Near Lampeter, in the neighbourhood of the latter river, there is much false bedding in these deposits. In the high grounds, scattered instances may be seen on the hills between Llanidloes and Machynlleth.

It has been shown, that after the catastrophe which immediately preceded the appearance of the new red sandstone, no great movement of the land occurred anterior to the denudations of comparatively late tertiary epochs; using the term *great* with reference to measurements compared with the upheaval of Wales, attendant on the contortion of all its strata, from the coal measures downwards. Assuming this, it is evident that greater, or perhaps, more frequent movements, as regards this district, must then have taken place, than any intervening between that catastrophe and the Tertiary period. These movements seem to have been attended with great, and probably very gradual depressions, submerging the whole country, as deep, at least, as the height of the highest existing land, since, without this submergence, the rocks formerly superincumbent on the strata now occupying such positions, could not have been brought within the denuding influences of the sea. There is, however, no reason to conclude that the land may not have sunk to a still greater depth. It is unlikely that this depression was effected suddenly, since, in the surrounding unconformable strata, there is no evidence of any universal and violent disturbance. As the land sank, the waves, which had not touched these shores for countless ages, once more began the work of destruction on hills long placed high above their reach. If the submergence were exceedingly slow, the amount and thoroughness of the progressing denudation would be proportionally great, the matter removed being spread over that which, lately land, had now become a sea bottom, deepening rapidly seawards, but shallow close in shore where the waste of land was in progress. If the depression were rapid, then the great natural inequalities of the yet undenuded land would form long hollows, arms, and deep troughs in the sea, the debris being thrown into their recesses, to be again displaced by subsequent denudations (consequent on further movements), together with the more solid surface-beds on which it rested.

When the high ground constituting the restored portions of the sections was, in the progress of geological events, removed, the land again uprose to attain its present elevation; and if, during the progress

of this general upheaval, occasional oscillations of level occurred (and this seems to have been the case), then the destroying agency of the waves would act, in favourable conditions, with increased power. And thus, in the long lapse of geological time, as the land slowly reached its existing height, the restless action of the sea gave to our hills and valleys the normal outlines of their present forms, since but slightly modified by atmospheric agencies, the loose drifty deposit that covers the hills and valleys so formed, being, as it were, but the dregs of the matter removed from the rising land during its last elevation.

This paper being but an opening of the subject as regards the denudation of the older rocks of Wales and its neighbourhood, it is not intended at present to enter fully on all the details of the times and means by which the denudations of the country were effected, till data for North Wales have been collected of as accurate a character as that now published in the six-inch sections. It being understood, however, that the great outlines of the country are entirely referred to the action of the sea on the rocks in by-gone Tertiary times, it may be well to give an outline of the manner in which such an operation might have been effected.

The line of greatest waste on any coast, is the average level of the breakers.* The effect of such waste is obviously to wear back the coast, the line of denudation being a level corresponding to the average height of the sea. Taking *unlimited* time into account, we can conceive that any extent of land might be so destroyed, for though shingle beaches and other coast formations will apparently for almost any ordinary length of time protect the country from the further encroachments of the sea, yet the protections to such beaches being at last themselves worn away, the beaches are in the course of time destroyed, and so, unless checked by elevation, the waste being carried on for ever, a whole country might gradually disappear.

If to this be added an *exceedingly slow depression* of the land and sea bottom, the wasting process would be materially assisted by this depression, bringing the land more uniformly within the reach of the sea, and enabling the latter more rapidly to overcome obstacles to further encroachments, created by itself in the shape of beaches. By further gradually increasing the depth of the surrounding water, ample space would also be afforded for the outspreading of the denuded matter. To such combined forces, namely, the *shaving away* of coasts by the sea, and the spreading abroad of the material thus obtained, the great *plain* of shallow soundings which generally surrounds our islands is in all probability attributable.

* See De la Beche's 'How to Observe,' and 'Theoretical Geology.'

It is remarkable how certain of the sections themselves seem to point to such ideas. If we refer to those, the seaward slopes of which partly run towards Cardigan Bay (6-in. Sheet, Nos. 4, 5, 6), it cannot but be remarked, that with the exception of the transverse valleys, the general slope of the country from various elevations down to the present coast cliffs is remarkably uniform and gradual. In Sheets, Nos. 4 and 6, the average slopes for many miles towards the sea, do not exceed one degree. The unassisted eye often comprehends the same truth, especially in great part of the country between Aberystwyth and Cardigan, where looking north or south *across* the transverse valleys, the landscape frequently appears as a great and gently inclined plain with a seaward slope and bounded by distant inland hills, easily comparable to many an existing line of lofty coast.

Suppose the higher parts of the district between the Towy, near Galt-y-berg, and Nant-maen-llwyd, near the Brenig,* to have been above water while the country on the N.W. towards Cardigan Bay was submerged, and through the action of previous denuding agencies working in conjunction with slow progressive depression that the submerged rocks between Cardigan Bay and the high lands above water retained the same relative level to these lands as that which now obtains; then taking the difference of level between the ground immediately east of the existing coast and that at Bryn-brawd and Cerrig bela, the depth of water about 13 miles seaward would not exceed 150 fathoms.

The waves acting equally on cliffs of unequal hardness soon produce great irregularities of outline, the harder rocks standing out in bold promontories, while the softer materials yielding more rapidly to the shock of the breakers, slowly originate bays, creeks, and arms of the sea. If to this we add the influence of exposure to prevalent winds, the indented character of a coast often becomes very remarkable,† the general depth of the plain, so to speak, formed by denudation continuing the same, unless varied by oscillations of level. Besides those peculiarities of outline dependent on unequal hardness of rocks, the form of the escarpment bounding the surface beneath the sea, would of course be much modified by the dip and geological position of its component rocks, so that it sometimes happens that a soft material on account of the seaward slope of its beds, resists the power of the breakers longer than a harder substance placed under less favourable conditions. But as the chances are equal of these varieties being thrown into favourable or unfavourable positions, it will be found that in a great majority of cases, the promontories on a coast are formed of the less yielding material.

* Horizontal Sections of the Geological Survey of Great Britain, Sheet 4.

† See the west coast of Scotland and Ireland. Doubtless the Western Isles are but the fragments of a larger land.

Take for a modern example St. Bride's Bay, on the coast of Pembrokeshire. The softer purple slates of the Silurian rocks, and the black shales of the coal measures have been ground to pieces and washed out from between the north and south horns of the Bay, which consisting of hard green-stone, at their extremities, more strongly resisted the ceaseless grinding of the western breakers. The trap islands to the west of these promontories are doubtless but fragments of this territory. Here we have the rudiments of a short, wide-spreading and shallow valley. If the land were further elevated, the valley might gradually be deepened, for the trap rocks still resisting the breakers, the shales would again give way, and the depth of the hollow be increased according to the amount of elevation of the land.

By modifications of these causes islands are formed, which afterwards by further upheaval become the tops of hills. The flat sea bottoms surrounding such newly upheaved islands, are again subjected to denudations, and again unequal hardness and exposure produce further inequalities.

Thus by endless oscillations of level, the contour of a country assumes its varied outline. It is remarkable how frequently the hill-tops and the higher lands of Wales are more or less tipped with rock of superior hardness, such land having been saved or upheld, as it were, by reason of that hardness in the midst of the surrounding denudations. From the same operations most of the greater hollows have been scooped out by the destruction of softer materials. Two striking examples exist in the wide valleys of the Towy, and the low district lying beween the ranges of hills on the south of the Teifi and to the north of the Aeron. In both cases, the bounding hills are composed in great part of hard sandstones, the low ground consisting of softer slates and shales.

In the case of the vale of Towy the rudiments of the valley may have had a date as old as the first contortion of the strata. When the entire strata were bent to form the great anticlinal axis which here throws the Silurian rocks across the valley to the north, it is not improbable that a wide-gaping crack of more than ordinary dimensions existed at the apex of the curve, into which, when the denudations began, the waters gaining access to the soft rocks below, more readily effected the beginning of the excavating process, which has only terminated with the last upheaval of the land.

In numerous instances, valleys opening to the sea end in bays, it will be found that not unfrequently the headlands on either side of bays are composed of comparatively unyielding materials. Depre[ss] land, and these valleys become arms of the sea; raise it, and the[y] become a continuation of the valleys. If Pembrokeshire were eleva[ted] but 60 or 70 feet, Milford Haven would become a shallow valley of th[e]

nature, with occasional pools or small lakes in its hollows, through which would wind the waters now flowing into the haven. As Milford Haven now is, such at no very distant geological epoch were the Vales of the Aeron and Teifi, the Taf, and the Towy with its diverging branches, through which now flow the tributaries of the Gwilli and the Cothi.

To an experienced eye the whole physical structure of the country bears witness to the power and duration of the causes described. In the long, gentle slope of the country from the hills on the right bank of the Teifi to the sea, we observe the effects first of the planing away of surface irregularities during an average general depression, and again of the further scooping out of valleys in this plain during a subsequent average elevation. Such combinations go far to explain the whole matter. The flat-topped ranges of hills, common in these counties—in Monmouthshire, near Abergavenny—in Caermarthenshire, between the Towy and the Teifi—in the neighbourhood of Builth, in Brecknockshire and Radnorshire—and in many other places beside—are but evidences of the same planing processes, the original approximate levels being reduced to a more fragmentary condition by the after denudations that scooped out their intersecting valleys. In more broken ground, the same operations seem to have been carried on, only to a greater extent. Indeed, from the watershed, in its slope towards Cardigan Bay, as exhibited in the six-inch Sections (Sheets, No. 4, 5, and 6), an approximate straight line may be drawn from the higher ground to the coast cliff, barely touching the average higher points of the sections. This coincidence is not accidental, for the higher grounds are hard sandstones or arenaceous slates, the low lands that lie beneath that line being frequently composed of more easily denuded materials.

During the progress of these elevations and denudations, many of the higher lands must have formed groups of islands of various magnitude and form, some sloping gently to the sea, and others ending abruptly in high coast cliffs. The high grounds of the Llangeinor coal measure district, in Glamorganshire, form a good example of this description of land, its high, flat-topped ridges standing boldly out amid the winding, sea-excavated valleys. Similar appearances are common in the same coal field. The Forest of Dean is another striking instance of an ancient island saved from utter destruction by the accident of its coast of old red conglomerate and carboniferous limestone having long enough withstood the dash of the breakers, during the denudations that hollowed out the low land in the soft marls around. Other well-marked examples of old coasts exist near Rhayader Gwy, in the steep southern slope of Cefn-y-Gamrhiw, in the cliffs of Craig Twrch, near Lampeter, and in the old island-like land called Mynydd Mallaen, near Llandovery. These are all more or less composed of stubborn materials, especially the former

two, both being capped by beds of durable sandstone and conglomerate, resting on softer, slaty strata.

Of more extended lines of coast, one of the most marked examples exists in the long range of hills nearly coinciding with the strike of the tough tilestones from the neighbourhood of Builth far into Caermarthenshire, along the south side of the Vale of Towy. Another and far more marked example stands boldly out in the old red sandstone range of the Black Mountains stretching from the country near Hay, in Herefordshire, westward by the Beacons of Brecon and the Caermarthen Fans, and merging into the carboniferous limestone hills south of Llangadoc and Llandeilo. In an opposite direction, the same series of high grounds are continued round the east side of the Monmouthshire coal field, thus forming, as the land rose to certain heights, a strong coast barrier, protecting the coal measures during the progress of denudation by a sea in the midst of which, at the same period, the Forest of Dean and part of the adjacent country lay as an outlying island. In some of the hardest parts of this range, the old sea cliffs are still quite precipitous, strongly reminding the beholder of the high old red sandstone cliffs on the east coast of South Pembrokeshire. Such instances are especially remarkable in the rugged range near Brecon and in the wild precipices of the Caermarthen Fans.

And here it may be remarked, as intimately connected with this part of the subject, that the position which many large tracts have assumed, in consequence of the contortion of the strata, has been the means of saving much of the strata of these tracts from total denudation. This might easily be demonstrated in numerous instances, but is especially remarkable in certain cases when large tracts of coal measures have been so preserved, thus giving rise to the erroneous idea that they were originally deposited in the basins where we find them, in the manner they now lie.

Everything connected with the coal measures tends to show that they were accumulated in vast shallows, gradually or periodically depressed as the accumulations progressed. The vegetation forming the coal beds most probably grew on wide marshy flats, and hence, especially when taken in connexion with the evidence derived from the ordinary strata with which they are associated, it is evidently untenable that such beds were deposited at the high angles they often exhibit. It has already been shown that the Forest of Dean is but an outlying fragment of the great original coal field that mantles round Wales, saved from the cause previously assigned; but, independently of this explanation, it is plain that neither the sedimentary rocks nor the coal could have been originally formed, as they now lie, on the east side of the basin (Section No. 2, Pl. 4).

The same remark is equally applicable to the elder denudations effected by the seas of the new red sandstone and oolites, when great

patches of coal measures were saved from the wasting power of that sea, by means of the hollow troughs, where they lay securely sheltered. This is eminently the case in Somersetshire, in the country around the Mendips, and from thence towards the Avon (Section No. 4, Pl. 4).* The new red sea could not destroy that which lay beneath the level of its breakers. At that level it has planed the country across, its deposits resting on the edges of the beds, protected from its ravages because of their depressed position.

But the most splendid example of this nature, is to be found in the great coal field of Glamorganshire and Monmouthshire. There, as it originally existed after the contortion of the strata, the southern portion of the curved rocks was washed away by the sea of the new red sandstone, none of the coal measures being spared, except what may now lie preserved in the hollows corresponding to that between Mount Pleasant, and Twyn Bwm-Beggan (No. 5, Plate 5). But that which lay to the north was saved from this sea for a time by the hard sandstones and carboniferous limestone, rising boldly above the waters on the southern edge of the present field, the barrier so reared, withstanding the attack of the waves, till a further elevation of the country, during the oolitic periods, placed the whole beyond their reach. There it stood till the occurrence of the great depressions of Tertiary times, when denudation of the country commenced anew. During that period of protracted devastation, the coal measures were again in great part saved by the strong elevated rim that surrounds the basin where they lie, and though thousands of vertical feet have been destroyed by denudation, the principal portion of this great fragment of the original coal field still remains partly above, but the greater part below, the level of the sea (6-in. sheets, Nos. 7, 8, 9, 11, and 12).

It is not to be expected that an unaccustomed eye should at first sight detect all the evidences of the former action of the sea on these lands. Once fairly above water, atmospheric influences acting on the surface, rounded the sharp edges of the jutting rocks, and smoothed the general contour of the country. This may be seen still going on in many a cliff, where great heaps of fallen angular debris choke up the surface below. The power of running water has also considerably modified the surface, but the part it has played is trifling compared with the effects that have sometimes been attributed to its agency. How small a part has been acted by rivers and streamlets in scooping out the valleys of the country, is shown by the fact that in the low lands they have rarely succeeded in cutting through the superficial drift, or relics of the old sea bottoms that have remained on the land during its latest elevation.

* The proofs of this will be better seen by reference to the 6-inch sheets, Nos. 14, 15, 16, and 17.

Even in the higher grounds of Cardiganshire and its neighbourhood when the mountain torrents have cut through this drift, they have seldom exerted much influence on the rocks below; and where, under favourable circumstances, deep gullies have been worn, the original contour of the ground which first gave them a tendency to do so is easily discernible. In the larger valleys, where the streams are sluggish, instead of assisting in further excavations, the general tendency is often rather to fill up the hollow with alluvial accumulations, and so help to smooth the original irregularities of the surface. We must, therefore, either adopt the theory that the great features of the land have resulted from the ordinary action of the sea, or else revert to the hypothesis of great bodies of water violently rushing over the surface and sweeping suddenly away masses of matter vaster in amount than the whole land of the district now above the level of the sea; and this not in the small corner of Wales alone, for it may safely be predicted that similar observations might readily be extended over countries of much wider extent. Again, the arrangement of the valleys stretching (but not from a centre, or series of centres) towards every point of the compass, militates against the idea of their being scooped out by sudden rushes of water. That such phenomena may have locally influenced the superficial detritus is easily credible, but not that they produced the configuration of these lands.

During the progress of the latter denudations, it must be recollected that our western coasts were not then, as now, so effectually protected from the western swell by Ireland. If the same depression extended to Ireland, that country must then have presented a group of islands, bearing the same relation to these shores that the Western Isles now do to Scotland. We might thus expect in these early times far greater irregularity of outline than we now find on the coast of Wales. This has been already shown in describing the denudation of the country, which itself presented a group of islands, probably contemporaneous with the Irish cluster further west. In this case, the loose deposits that overspread the surface may be of the same general date as the Irish Tertiaries surrounding these old islands, and this I expect will be found to be the fact when the observations begun by Mr. Trimmer, on Moel Tryfan and other parts of Caernarfonshire,* shall be more widely extended.

If we survey the ragged outlines of the western coasts of Ireland and of Scotland, it is easy to conceive how the power of the Atlantic breakers could, in the course of innumerable ages, have ground to pieces so much of the solid strata, and left the remains as islands amid the waves. Indeed, in the cliffs of the Black Mountain range there is every proof that they were formed by the action of an old Atlantic, which was then,

* Geological Proceedings, vol. i. p. 333.

as now, the restless agent whose force wastes the western shores. At a still later period, when Wales had attained almost its present elevation, the same Atlantic, acting on the chalks and oolites, formed those abrupt escarpments stretching north and north-east from Lyme Regis, which, in all but the want of water, even to an unaccustomed eye, present the semblance of a modern coast, with its bays, lochs, and outlying islands.* At this period, the lias and new red sandstone being slowly denuded of their overlying strata, a strait of variable width occupied the lower lands, now forming part of the counties of Chester, Stafford, Worcester and Gloucester; the Welsh counties, and high lands, to the north-east, forming a line of coast opposite to the oolitic cliffs, on the eastern side of the strait. Thus Wales may have at this period become an island.

Reasoning back from these considerations to the axiom with which we started, it will be remembered that all strata mechanically deposited were formed by the waste of pre-existing rocks.

In South Wales the Silurian rocks attain a thickness of at least 12,000 feet. The greatest thickness of the old red sandstone is between 7,000 and 8,000 feet; and the coal measures attain in their greatest development, a thickness of not less than 12,000 feet. Simply estimating their cubic contents in the area they now occupy, and adding to this the amount removed by denudation, and that existing beneath the level of the sea, it is evident that the quantity of matter employed to form these strata was many times greater than the entire amount of solid land they now present above the waves. Now, though in South Wales a small proportion of this material may have been used twice over in the formation of its older strata, yet, from the almost perfect conformity of these deposits, it is evident that this is the exception, and not the rule. To form, therefore, so great a thickness, a mass of matter of nearly equal cubic contents must have been won by the waves and the outpourings of rivers from neighbouring lands, of which, perhaps, no original trace now remains. It has been already stated that a greater amount of carbonic acid in the ancient atmosphere than it now holds may have materially accelerated the process of disintegration by the union of this acid with the alkaline constituents of rocks. And thus these earlier deposits may well have accumulated more rapidly than those of modern eras. Yet, with every allowance on this head, when we consider the many phases through which creation passed during the development of these various formations,—genera and species in many successions coming slowly into being, disappearing and being replaced by others; when we consider the solid cubic contents of the aggregate strata as they existed when entire, or even as they now are (for a far

* First suggested by Sir Henry De la Beche.

greater proportion of their mass lies beneath than above the level of the sea), we cannot but conclude, when compared with the little surface they now present above water, that the time occupied in their formation must have been infinitely longer than the time required to destroy all that now remains exposed to the elements, or all that existed even prior to the tertiary denudations. If the same agencies be still at work, that which has been achieved once may be performed again. Why, then, should we wonder at the destruction of the old land depicted in the restored sections. Yet the matter torn from above the present surface was *far greater* than all which still remains above the level of the sea. In these last denudations, judging from the organic remains of the period, we may not suppose that the atmosphere sensibly differed from that of our own times, and thus from the air there would arise no acceleration in the waste. What, then, can we conclude, but that the time requisite to remove these mountains was at least equal or greater in amount than that which may yet pass ere the existing land of the same district be utterly worn away.

As we estimate time, it is vain to attempt to measure the duration of even small portions of geological epochs. Within the historical period no great authentic change has been effected on the coasts of Wales. On many an available headland, the cliffs are still crowned with ancient fortified retreats, whose origin is lost in the mists of antiquity. If, then, we cannot contemplate the far distant period when the present land shall be utterly destroyed, so also of the time occupied in that last great denudation in days we may almost call but little antecedent to our own, if it were possible to express so vast a period in figures, they could convey no impression to the mind save one almost approaching to infinity.*

* For much valuable information on a subject closely connected with the foregoing remarks, the reader is referred to a paper 'On the elevation and denudation of the district of the Lakes of Cumberland and Westmorland, by W. Hopkins, Esq.,' Geological Proceedings, vol. iii. p. 757. The disturbances in that district are, it is evident, intimately connected with many of those here treated of; and it will be matter of much interest, when information on these heads is accurately collected over all our islands, to work out the physical geology of our country on a more extended scale, with sufficient data, perhaps, on which to found reasonings for much of our ancient geological geographies.

On the Connexion between the Distribution of the existing Fauna and Flora of the British Isles, and the Geological Changes which have affected their area, especially during the epoch of the Northern Drift. By EDWARD FORBES, F.R.S., L.S., G.S., Professor of Botany at King's College, London, Palæontologist to the Geological Survey of the United Kingdom.

IN the following remarks on the history of the indigenous fauna and flora of the British Islands and the neighbouring sea, I take for granted the existence of *specific centres*, *i. e.*, of certain geographical points from which the individuals of each species have been diffused. This, indeed, must be taken for granted, if the idea of a species (as most naturalists hold) involves the idea of the relationship of all the individuals composing it, and their consequent descent from a single progenitor, or from two, according as the sexes might be united or distinct.

That this view is true, the following facts go far to prove. 1st. Species of opposite hemispheres placed under similar conditions are *representative* and not *identical*. 2nd. Species occupying similar conditions in geological formations far apart, and which conditions are not met with in the intermediate formations, are representative and not identical. 3rd. Wherever a given assemblage of conditions, to which, and to which only, certain species are adapted, are continuous—whether geographically or geologically—identical species range throughout.

I offer no comments on these three great facts, which I present for the consideration of the few naturalists who doubt the doctrine of specific centres. The general and traditional belief of mankind has connected the idea of descent with that of distinct *kinds*, or species, of creatures; and the abandonment of this doctrine would place in a very dubious position all evidence the palæontologist could offer to the geologist towards the comparison and identification of strata, and the determination of the epoch of their formation.

Moreover, it is notorious that the doctrine of more than one point of origin for a single species, and consequently more than one primogenitor for the individuals of it, sprung out of apparent anomalies and difficulties in distribution, such as those which I am about to show can be reasonably accounted for, without having recourse to such a supposition.

Having assumed the doctrine of *specific centres* as true, the problem to be solved is, *the origin of the assemblages of the animals and plants*

now inhabiting the British Islands. The zoological works of Fleming, Jenyns, Yarrell, Bell, and W. Thompson, have enumerated the species and treated of the distribution of our indigenous animals, those of Smith, Hooker, Lindley, Babington, Henslow, and especially Watson, have done the same service for our *native flora;* but the history of the *formation*, if I may so say, of that fauna and flora, remains to be investigated. This essay is offered as a contribution towards such a history.

There are three modes in which an isolated area may become peopled by animals and plants.

1st. By special creation within that area.

2nd. By transport to it.

3rd. By migration before isolation.

The first of these modes, if it operated at all within the limited area under examination, had but very little influence in determining the vegetation and animal population of the British Isles, since, with a very few, mostly doubtful, exceptions, the terrestrial animals and flowering plants within their area are identical with continental species.

The second mode is not a sufficient one; for, though doubtless the great mass of cryptogamic plants, a few phanerogamia, and a few terrestrial animals, besides those endowed with powers of flight, may have found their way across the separating waters by the agency of currents, &c., or in the case of plants, their seeds have been conveyed by the winds or birds through the air, yet, after making full allowances for all likely means of transport at present in action, there remains a residue of animals and plants which we cannot suppose to have been transported, since either their bodily characters or certain phenomena presented by their present distribution, prevent our entertaining such an idea. For, when we consider that within this limited area a great number of animals and plants are not universally dispersed, but congregated in such a way as to form distinct regions or provinces, which have remained unchanged as long as we have any record, we can hardly grant transporting powers to have operated so far as to sketch out those regions in the likenesses of distant and distinct lands, and yet not afterwards to have continued their action, so as eventually to have merged them all into an homogeneous whole.

There remains the third mode by which a land may be peopled; namely, by colonization from another or from several neighbouring lands previous to isolation. This, of course, involves the consideration of geological causes, the part played by which in the present disposition of organized beings on the surface of our globe, has never as yet received due consideration. It is through this mode, I believe, the British Islands have chiefly acquired their fauna and flora; but, before showing how, it may be well to point out certain peculiarities presented by their

natural history, well known and placed on record by British botanists and zoologists. The consideration of them has caused me to make this attempt towards ascertaining the causes by which they were produced.

The vegetation of the British Isles presents a union of five well-marked floras, four of which are restricted to definite provinces, whilst the fifth, besides exclusively claiming a great part of the area, overspreads and commingles with all the others.

I. Commencing with the smallest, we find the mountainous districts of the west and south-west of Ireland characterized by botanical peculiarities which depend on the presence of a few prolific species belonging to the families *Saxifrageæ*, *Ericaceæ*, *Lentibulariæ*, and *Cruciferæ*. The nearest points of Europe where these plants are native is the north of Spain. The species are—

Saxifraga umbrosa.
Saxifraga elegans.
Saxifraga hirsuta
Saxifraga Geum.
Saxifraga hirta.
Saxifraga affinis.
Erica Mackaiana.
Erica mediterranea.
Dabæcia polifolia.
Arbutus unedo.
Pinguicula grandiflora.
Arabis ciliata.

There are two or three other species, including *Allium Babingtonii*, which possibly belong to the same assemblage.

There is no evidence of any local assemblage of animals corresponding to this flora.

II. In the south-west of England and south-east of Ireland we find a flora which includes a number of species not elsewhere seen in the British Isles, and which is intimately related to that of the Channel Isles, and the neighbouring part of France. In the Channel Isles we find them associated with a number of plants which are not natives of England or Ireland. Such are *Ranunculus ophioglossifolius*, *Sinapis cheiranthus*, *Erucastrum incanum*, *Arthrolobium ebracteatum*, *Centaurea Isnardi*, *Linaria pelisseriana*, *Echium violaceum*, *Orchis laxiflora*, *Allium sphærocephalum*, &c., plants which mark the commencement of the type of vegetation characteristic of Southern Europe. They are accompanied by terrestrial mollusca of the same climatal stamp, such as *Helix aperta* and *Helix revelata*, both first noticed in Guernsey by myself in 1839; the former is there at its most northern limit, and the latter only extends further into Devonshire. Thither it accompanies a

number of plants of the same climatal type with those enumerated above, but whose range does not extend beyond this corner of England. Such are *Helianthemum polifolium, Tamarix gallica, Hypericum linearifolium, Oxalis corniculata, Lotus hispidus, Corrigiola littoralis, Polycarpon tetraphyllum, Bupleurum aristatum, Physospermum cornubiense, Lobelia urens, Erica ciliaris, Salvia clandestina, Trichonema columnæ,* and *Scilla autumnalis.*

In the south-east of Ireland we find the number of plants of this Gallican type greatly diminished; whilst such as are present are species met with also in the south-west of England. Such are *Matthiola sinuata, Senebiera didyma, Medecago denticulata, Rubia peregrina, Antirrhinum orontium, Linaria elatine* and *italica, Scrophularia scorodonia, Sibthorpia Europœa, Erica vagans, Cicendia filiformis, Teucrium scordium, Hottonia palustris,* and others.

This is the *Atlantic type* in Mr. Watson's arrangement of British types of vegetation.

Helix pisana extends its range through a great part of this region. *Testacellus haliotoideus* is confined to the English portion of it. This was possibly the parent British fauna of *Bulimus acutus.* The presence of the *Bufo calamita* (the Natter Jack) in Ireland is probably also proper to this province.

III. In the south-east of England, where the rocks of the cretaceous system are chiefly developed, we find the vegetation distinguished by the presence of a number of species common to this district and the opposite coast of France. Here are the localities of the well-known *chalk* plants, much sought after by botanists from the north. They form part of Mr. Watson's second, or Germanic, and of his third, or English, type of British vegetation.

Thlaspi perfoliatum, Linum perenne, Genista pilosa, Onobrychis sativa, Bryonia dioica, Caucalis daucoides, Dipsacus pilosus, Inula conyza, Centaurea calcitrapa, Phyteuma orbiculare, Gentiana pneumonanthe, Verbascum lychnitis, thapsiforme, and *blattaria, Salvia pratense, Ajuga chamæpitys, Buxus sempervirens, Tamus communis,* and many species of *Orchideæ,* though not all *chalk* plants, are members of this flora. *Clematis vitalba,* and some other plants, appear to be equally members of it, and of the last region.

The peculiar character of the entomology of the south-east of England is intimately connected with the presence of this flora, and also that of the pulmoniferous mollusca, which here include several species, as *Helix pomatia, Helix obvoluta, Helix limbata, Helix carthusiana* and *carthusianella, Clausilia ventricosa, Clausilia Rolphii,* and *Bulimus montanus,* either confined to this district, or very rarely found beyond it in Britain.

IV. The summits of our British Alps have always yielded to the botanist a rich harvest of plants which he could not meet with elsewhere among these islands. The species of these mountain plants are most numerous on the Scotch mountains,—comparatively few on more southern ridges, such as those of Cumberland and Wales. But the species found on the latter are all, with a single exception (*Lloydia serotina*), inhabitants also of the highlands of Scotland; whilst the alpine plants of the Scotch mountains are all in like manner identical with the plants of more northern ranges, as the Scandinavian Alps, where, however, there are species associated with them which have not appeared in our country. This progressive diminution of alpine forms southwards is an important fact, the interpretation of which will presently appear.

The first plant of this Scandinavian type which disappears southwards is the *Arenaria norvegica*, confined to the most northern of the Shetland Isles. On the northern shores of the mainland a beautiful primrose, the *Primula scotica*, formerly supposed to be peculiar to the country after which it is named, but found by me abundantly in Norway in 1833, appears and ceases. A rich assemblage of these northern forms are distributed over the Scottish Alps, but do not reach the English mountains. Such are *Draba rupestris, Lychnis alpina, Arenaria rubella, Astragulus alpinus, Sibbaldia procumbens, Saxifraga cernua, Saxifraga rivularis, Arctostaphylos alpina, Phyllodoce cærulea, Azalea procumbens, Gentiana nivalis, Myosotis suaveolens, Veronica alpina, Veronica saxatilis, Salix arenaria, Betula nana,* and many species of *Juncus, Luzula,* and *Carex*. Of these the *Phyllodoce cærulea* (a plant highly characteristic of the Norwegian Alps) has either disappeared lately, or is likely soon to be extirpated, having fallen a victim to the ardour of collectors, who will, probably, ere long, extirpate many more of our alpine rarities, and reduce them to the rank of doubtful natives—like *Eriophorum alpinum*, now certainly extinct. To the same category with the above belong some plants less truly alpine, and not ranging south of Scotland, as *Moneses grandiflora, Pinguicula alpina, Ajuga pyramidalis, Goodyeria repens, Corallorhiza innata,* and certain species which reach the north of England, as *Cornus suecica, Linnæa borealis,* and *Trientalis Europæa*, all very characteristic Scandinavian species. To the Welsh mountains but few of these alpine and northern forms reach, but among them are some of the most characteristic. Such are *Arabis petræa, Cerastium alpinum, Potentilla alpestris, Sedum villosum, Saxifraga muscoides, Saxifraga nivalis, Erigeron alpinum, Salix reticulata* and *herbacea, Juncus filiformis,* and *Juncus triglumis.*

In Ireland, also, a few of these alpine or sub-alpine plants of Scandinavian origin are found, probably derived from the same source, and

with them some of those inhabiting the low country, such as *Lamium intermedium*, a common plant also in Scotland.

The fauna of our mountain regions, so far as it is developed, bears the same relation to more northern countries. The alpine hare (*Lepus variabilis*), the ptarmigan, and the capercailzie (now extinct), may be cited among the higher animals; and the insects which give a character to the entomology of the Highlands are Scandinavian forms. The absence of peculiar pulmonifera is as good evidence as the presence of the insects, for whilst almost every mountain region in Europe is distinguished for its peculiar *Helices* and their allies, the British, like the Scandinavian Alps, are remarkable only for their deficiencies.

The *Highland*, and part of the *Scottish* and *Hebridean* types of British vegetation, as defined by Mr. Watson, agree with the fourth flora, as defined above. In his *Hebridean* type he includes the rare *Eriocaulon septangulare*, a very remarkable plant, known in Europe only in the Hebrides, and Connamara, in the West of Ireland; elsewhere it is an inhabitant of Boreal America, which is its true native country, and from whence, either by means of transport, now or anciently in action, it has, in all probability, been introduced *naturally* into the British Isles.

V. The fifth and general flora of the British Islands—everywhere present, alone or in company with the others—is identical as to species with the Flora of Central and Western Europe—that which may be properly styled *Germanic*. Such of its members as are generally distributed compose the *British type* of Mr. Watson, whilst its more local species are distributed among, and form part of his *Germanic*, *English*, and *Scottish* types. This is a flora which has overspread many local floras throughout Europe, and given a general character to the vegetation derived from the presence of such truly common species as *Bellis perennis*, *Primula acaulis*, *Ranunculus acris*, *Ficaria ranunculoides*, *Cardamine hirsuta*, and our most common trees and shrubs. Its scarcer plants are of more interest, from the clear manner in which they mark the progress of the flora, and the line it took in its advance westwards. Thus, we find still limited to the eastern counties of England, such species as *Anemone pulsatilla*, *Myosurus minimus*, *Turritis glabra*, *Frankenia lævis*, *Holosteum umbellatum*, *Schleranthus perennis*, *Artemesia campestris*, *Melampyrum cristatum*, *Veronica verna*, *Veronica triphyllos*, *Stratiotes aloides*, and *Sturmia Loeselii*. Others again, whilst [illegible] extended over considerable tracts, or into several districts [illegible] and Scotland, have not found their way to Ireland, as *Thalic*[illegible] *Ranunculus hirsutus*, *Diplotaxis tenuifolia*, *Thlaspi alpestre*[illegible] *viscosus*, *Stellaria nemorum*, *Genista anglica*, *Astragulus hy*[illegible] *Spiræa filipendula*, *Potentilla verna*, *Ligusticum scoticum*, *V*[illegible] *dioica*, *Scabiosa columbaria*, *Campanula glomerata*, *Gagea lutea*, [illegible]

calamus. Some, such as *Primula farinosa*, *Lysimachia thyrsiflora*, and *Convallaria verticillata*, seem to indicate a more northern point of derivation of this Germanic flora than that from whence the main part of its assemblage of plants came. It is remarkable that certain species of this flora, which flourish best on limestone, such as *Scabiosa columbaria*, *Sison amomum*, *Campanula glomerata*, and others, are not found in the limestone districts of Ireland, and in like manner certain species, which everywhere, when found, delight in sand, as *Ajuga chamæpitys* (more properly a member of III. than of V.), are also wanting on such Irish localities as are best adapted for them.

The fauna which accompanies this flora presents the same peculiarities, and diminishes towards the north and west. This is very observable, both among the native vertebrate and invertebrate animals. Thus, among quadrupeds, the mole, the squirrel, the dormouse, the polecat, and the hare of England (*Lepus timidus*), are confined to the English side of St. George's Channel, not to mention smaller quadrupeds. So it is also with the birds of short flight; so most remarkably, no less than half the species being deficient, with the reptiles; so also with the insects, and the pulmoniferous mollusca.* Among the latter animals are several species, which mark the fauna of the Germanic type as distinct from those of the more southern provinces. Such are *Helix scarburgensis* and *excavata*, *Clausilia dubia*, and *Pupa alpestris*.

In the preceding summary view of the regions or provinces into which our flora and fauna may be divided, I have gone into no further detail than is necessary for the display of their principal and characteristic features, such as may be grasped by persons not familiar with the abundant details and material amassed in our British faunas and floras, which are more complete probably than those of any other country. It is this very completeness which enables us to pursue such inquiries as the present, which, indeed, could not be entered upon with advantage unless there were abundant data gathered together. The essays of Mr. H. C. Watson may be cited as among the most remarkable, and to them I must refer geologists who would wish to learn more respecting our indigenous flora, than it is here necessary to state.

It cannot be expected that in this stage of the inquiry all exceptional cases in our flora and fauna can be explained. There are several extremely difficult of explanation, but they are neither so numerous nor of sufficient importance to affect the general argument, and may safely be put aside for the present, in the certainty that the progress of research will ere long make clear the most doubtful.

To determine the how and when of these peculiarities, on the suppo-

* See Mr. W. Thompson's Reports.

sition that they are mainly due to—indeed, the only course left—migration before isolation of the area, it is necessary, if possible, to ascertain two fixed points in time, between which the migration or migrations must have taken place.

The eocene tertiary epoch—that of the deposition of the London clay—affords a first or most ancient point, after which only such migrations could have taken place; for we have abundant evidence that both the flora and fauna of such parts of the area under examination as were above water, were then very distinct from those which now occupy it, and enjoyed a climate far warmer than suitable to its present (terrestrial) inhabitants.

The epoch usually designated "historical"—that during which man has been a known inhabitant of the earth—affords a last point, one before which the migrations (at least, for the most part) took place. For the great deposits of peat, formed in part out of the remains of vast forests, which probably, during the earliest stages of the true historical epoch, covered a great part of the existing area of the British Isles, in many places overlie the fresh-water marls of the post-pliocene epoch, during which the *Cervus megaceros* flourished, themselves overlying and occupying depressions in the pleistocene tertiaries, formed of the upheaved bed of the sea of the glacial period.

During the post-pliocene epoch, over the elevated bed of the glacial sea, the great mass of the flora and fauna of the British Isles migrated from the Germanic regions of the continent. The whole of the flora I have numbered V., including the great mass of British plants, is Germanic. Every plant *universally* distributed in these islands is Germanic; every quadruped common in England, and not ranging to Ireland or Scotland. The great mass of our pulmoniferous mollusca have also come from the same quarter. Certain botanical and zoological peculiarities are presented by the eastern counties of England. In every case we find these to depend on Germanic plants and animals arrested in their range. The number of species of the Germanic type diminishes as we go westwards, and increases when we cross the German Ocean. On the other hand, the peculiarities of the Irish and Scottish faunas and floras depend either on the presence of animals and plants which are not of the Germanic type, or on the absence of English species, which are. When we turn to plants and mollusks which affect localities presenting certain mineral peculiarities, such as limestone plants and animals, as they are called, and which are consequently never generally diffused, we find that the species of the Germanic type are deficient westwards—in Ireland, for instance, where conditions favourable to their presence and diffusion occur abundantly. To what else can we attribute such peculiarities, unless to arrestment of the

migration of the Germanic types? And when we know that the Irish Sea is scooped out of the elevated bed of the sea of the glacial epoch, masses of which, of great extent and thickness, we find bounding its sides in England, the Isle of Man, and still more conspicuously in Ireland, and that on the great pleistocene plain lived the *Cervus megaceros*, can we doubt that over it the mass of Germanic types, forming the existing flora and fauna of Ireland migrated?—and that the migration of the species, less speedy of diffusion, which are now peculiar to England, was arrested by the breaking up of that land of passage—and thence the famous deficiencies of the Sister Isle, as for instance its freedom from reptiles, as, indeed, the excellent comparative Table of the Reptilia of Belgium, England, and Ireland, given by Mr. Thompson in his valuable Report on the Irish fauna, affords abundant proof.

	Belgium.	Britain.	Ireland.
SAURIA.			
Lacerta	3	2	1
Anguis	1	1	..
OPHIDIA.			
Coluber	2	..	..
Natrix	1	1	..
Vipera	2	1	..
BATRACHIA.			
Rana	2	1	1
Bombinator	3	..	..
Hyla	1	..	..
Bufo	2	2	1
Salamandra	1	..	..
Triton	4	3	2

On what did the difference (which is wholly numerical, and not specific) between the reptile population of Britain and Belgium, exhibited in this table, depend? On the same cause on which the difference between the flora and fauna of the east of England and Germany depends—on the breaking up of the upheaved bed of the Germanic Ocean of the glacial period, which possibly, indeed probably, was effected more slowly, and completed at a later time than the separation of Britain and Ireland.

But though the migration of animals and plants over the great Germanic plain will account for the major part of our British species which come from the west, we have in the mountain districts of Scotland, England, and Wales, a considerable flora, and a portion of our fauna, which cannot be traced to such a source, seeing that they are

not inhabitants of the ancient west of Europe, but of Scandinavia. How did they come? The alpine character of most of them forbids us by any stretch of probability to conduct them across the Germanic plain from its most northern bound, though some few plants, giving a peculiarity to the flora of the north-east of England and south-east of Scotland probably were so derived. But these I regard as Germanic. The plants and animals now under consideration could not have migrated hither after the destruction of the Germanic plains, for by that time the British Isles had assumed their present forms, and the localities of these species had become mountain tops. We have seen that the great Germanic and central British plains themselves were portions of the elevated bed of a pre-existing sea, which sea, when we trace its relics, is found to have covered a great part of the British Isles as now exposed, so that during its existence our mountains must have been comparatively low islands. This was the sea of the *Glacial* period, properly so styled, when the climate of the whole of northern and part of central Europe, was very different from what it is now, and far colder. The remains of the marine animals found in the strata deposited in that sea indubitably prove this fact, and, as will be seen presently, the flora of its islands as fully bears out such climatal evidence. This was the epoch of glaciers and icebergs, of boulders, and groovings, and scratches. It exhibited conditions physical and zoological, similar—indeed, nearly identical—to those now to be met with on the north-eastern coasts of America within the line of summer-floating ice. Extend that line across the southern half of Ireland and England,—not farther south, as we have evidence to show,—continue it eastwards, so as to strike against the Ural chain (as Sir Roderick Murchison has proved in his great work on Russia), and within that vast area you will have a condition of climate which will account for all the organic phenomena observed in the boulder clays and pleistocene drifts.

Now it was during this epoch (the epoch of my IVth flora), that Scotland and Wales, and part of Ireland, then groups of islands in this ice-bound sea, received their alpine flora and a small portion of their fauna.* Plants of subarctic character then would flourish to the water's edge, but when a new state of things commenced, when the bed of the glacial sea was upheaved, its islands converted into mountains, its climate changed, and a suitable population of animals and vegetables diffused over its area, the plants of the colder epoch survived only on the mountain regions which had been so elevated as to retain climatal conditions similar to those which existed when those regions were low ridges or islands in the glacial sea.

The general fauna and flora of our country being accounted for, and

* The capercailzie, the *Lepus variabilis*, &c.

also the peculiarities of the British alps, there still remain certain limited assemblages of organized beings which present distinctive characters, and for which the geological operations just referred to would not account. These are three in number. 1st. The animals and plants which give a peculiar character to the south-east of England, and inhabit, for the most part, the chalk districts. 2nd. The animals and plants which distinguish the south-west of England and the south-east of Ireland, species mostly indigenous also in the Channel Isles: and, 3rd. The assemblage of plants (small as to number of species but playing an important part in the general vegetation) giving a peculiar and very remarkable character to the flora of a considerable part of the west of Ireland.

These three sub-floras are all allied to, and derived assemblages of European plants south of the great Germanic group. As the south of England and of Ireland were in all probability unsubmerged during the Glacial epoch, they may have come over either before, or during, or after that period. There are strong reasons for believing they migrated before. As a general rule, we may regard the most southern floras to be oldest, especially when, as in these cases, they are more and more fragmentary, and their character is more and more southern.

That which I have numbered III. is the most extensive, and from the number of species which are exclusively or chiefly found in chalk districts in this country, I have called it the Kentish flora. But the attachment of such plants to chalk is an accident, and not an essential habit of the species; the preference is simply for calcareous districts. In other countries they are found indifferently on most forms of limestone, and on calcareous sands and clays. Botanists who write of such and such plants being present because the chalk is present, forget that, unless they be species peculiar to the locality examined, they must owe their presence to diffusion from some other, since chalk of itself has no power to call up any species, by an equivocal or spontaneous generation of it. And when a so-called chalk plant is not found on limestones adapted to it beyond (in our case, north of) the chalk, we must attribute its absence rather to geographical causes and impediments to its extension in that direction. This flora is evidently derived from the north-western provinces of France, and as no geologist doubts the ancient union of the two sides of the Channel, the course it pursued in migrating to England is sufficiently obvious. The epoch of the formation of the Straits of Dover would mark the period of its isolation, and if that breach of continuity was effected before the destruction of the great Germanic plain, as is probable, we may regard the Kentish flora as very ancient. Still more ancient appears to have been the flora numbered II., the pecu-

liarities of which are seen more especially in Cornwall and Devon, and in the south-east of Ireland. This flora—a relic of a larger—is undoubtedly a part of that which we find in the Channel Isles, and in the adjacent provinces of France. It is still more southern in character than No. III., exhibiting the features of the transition between the great flora of central Europe and that of the southern or Mediterranean region.

When we look to the geological features of the districts occupied by this Devon or Norman flora, we see that its course is marked by the remains of a great barrier, the destruction of which probably took place anterior to that of the formation of the higher and narrower parts of the Channel. It marks, too, the course of the southern bound of the glacial sea.

But whilst I incline to the view that the Kentish and Devon floras are anterior in migratory origin to the Glacial and Germanic, yet I do not press it as essential. For since the Straits of Dover could not have been opened out until the destruction of the greater and all the central part of the Germanic plain, it might fairly be held by those who may object to the survival of the two floras in question, when bounding the glacial sea, that their migration was coeval with the Germanic migration; that the English Channel is of post-pliocene origin, and that the great Devonian barrier was not destroyed until the close of the Glacial period. The holders of such a view would, of course, reduce the epochs of migration to three, instead of five. Such a view would not in the least affect the general truth of my theory.

Whatever doubts may be entertained respecting the antiquity of the Kentish and Devon floras, there can be none (if my premises be granted) respecting that which I have numbered I., and from which the peculiar botanical character of the south-west and west of Ireland is derived. The number of species included in it does not reach a score, but most of them play an important part in the mountain vegetation of the region. The remarkable point concerning these plants (for as yet no terrestrial animals of this period have been noticed, nor from what I shall presently have to say is it likely there are any now existing) is that they are all species which at present are forms either peculiar to or abundant in the great peninsula of Spain and Portugal, and especially in Asturias. No existing distribution of marine currents will account for their presence, and even if there were plausible grounds for attributing it to the great current known as Rennel's which sweeps the northern coasts of Spain, and strikes in its after-course against the western shores of Britain and Ireland, the plants in question, instead of being where they are, should be present in the southern districts of the countries bounding the English Channel,—in the region of the Devonian flora, *where they are not*. Nor can we suppose that

they have been conveyed as seeds through the air; for besides the important fact that they are all members of families having seeds not well adapted for such diffusion, and that the species of Compositæ and other plants with winged seeds associated with them in Spain are not present with them in Ireland, it would be very extraordinary if the winds which had conveyed them so far, had never, through, probably a long series of centuries, conveyed them still farther, and diffused them in a country where there are abundance of situations well adapted for their habitation. The hypothesis, then, which I offer to account for this remarkable flora is this—that at an ancient period, an epoch anterior to that of any of the floras we have already considered, there was a geological union or close approximation of the west of Ireland with the north of Spain; that the flora of the intermediate land was a continuation of the flora of the Peninsula; that the northernmost bound of that flora was probably in the line of the western region of Ireland; that the destruction of the intermediate land had taken place before the Glacial period; and that, during the last-named period, climatal changes destroyed the mass of this southern flora remaining in Ireland, the survivors being such species as were most hardy, saxifrages, heaths, such plants as *Arabis ciliata* and *Pinguicula grandiflora*, which are now the only relics of the most ancient of our island floras.

This, I admit, is a startling proposition, and demands great geological operations to bring about the required phenomena. With such a gulf as now intervenes between Ireland and Asturias it may seem fanciful and daring to suppose their union within the epoch of the existence of the plants now living in both countries. What then are the geological probabilities of the question?

During the epoch of the deposition of the miocene tertiaries there was sea—probably shallow—inhabited by an assemblage, almost uniform, of marine animals throughout the Mediterranean region (tertiaries of Cerigo, Candia, Malta, Corsica, Malaga, Algiers), across the south of France (Montpellier, Bordeaux), along the west of the Peninsula (Lisbon, &c.), and in the Azores (St. Mary's). I speak to the uniform zoological character of this sea from personal examination of its fossils. During the miocene epoch, then, we can suppose no union of Asturias and Ireland. But at the close of the miocene epoch great geological operations took place: witness the miocene marine beds discovered by Lieut. Spratt and myself at elevations from 2 to 6,000 feet in the Lycian Taurus. The whole of the bed of this great miocene sea appears to have been in the central Mediterranean and west of Europe pretty uniformly elevated. This then could—with every probability—have been the epoch of the connexion or approximation of Ireland and Spain. My own belief is, that a great miocene land, bearing the peculiar flora and fauna

of the type now known as Mediterranean, extended far into the Atlantic —past the Azores—and that, in all probability, the great semicircular belt of gulf-weed ranging between the 15th and 45th degrees of north latitude, and constant in its place, marks the position of the coast-line of that ancient land, and had its parentage on its solid bounds.* Over this land that flora, of which we have now a few fragments in the west of Ireland, might with facility have migrated. This would give us a new antidate, and enables us to declare our entire existing terrestrial flora and fauna as post-miocene.

The fact that there is a well-marked belt of miocene coast-line in North America (as shown by Mr. Lyell), and that the mollusca of that belt, as I have convinced myself from personal examination, indicate a representative, not identical, fauna in that region proves that during the miocene period there was an Atlantic gulf separating the new world

* The following extract from the writings of one of the first of living algologists, will show that there are *botanical* grounds for my speculation respecting the gulf-weed.

" Authors who have written on this *Fucus* have much disputed, both respecting its origin, and whether it continues to grow whilst floating about. Nothing at all bearing on the former question has yet been discovered; for though species of *Sargassum* abound along the shores of tropical countries, none exactly corresponds with *S. bacciferum*. That the *ancestors* of the present bank have originally migrated from some fixed station, is probable; but further than probability we can say nothing. That it continues to flourish and grow in its present situation is most certain. Whoever has picked it up at sea, and examined it with any common attention, must have perceived, not only that the plants were in vigorous life, but that new fronds were continually pushing out from the old, the limit being most clearly defined by the *colour*, which, in the old frond, is foxy-brown; in the young shoots pale, transparent olive. But how is it propagated; for it never produces fructification? It appears to me, that it is by breakage. The old frond, which is exceedingly brittle, is broken by accident, and the branches, continuing to live, push out young shoots from all sides. Many minute pieces that I have examined, were as vigorous as those of larger size, but they were certainly not seedlings, and appeared to me to be broken branches, all having a piece of *old frond* from which the young shoots sprung. As the plant increases in size, it takes something of a globular figure, from the branches issuing in all directions, as from a centre. On our own shores we have two species analogous to *S. bacciferum* in their mode of growth, namely, *Fucus Mackayi*, and the variety *B. sub-ecostatus* of *Fucus vesiculosus* (*F. balticus*, Ag.). Neither of these has ever yet been found *attached*, though they often occur in immense strata; the one, on the muddy sea-shore, the other, in salt marshes, in which situations, respectively, they continue to grow and flourish; and it is remarkable, that neither has ever yet been found in fructification, in which respect, also, they strikingly coincide with *S. bacciferum*. And if it be hereafter shown that *F. Mackayi* is merely *F. nodosus*, altered by growing under peculiar circumstances, may it not be inferred that *Sargassum bacciferum*,—which differs about as much from *Sargassum vulgare* as *Fucus Mackayi* does from *Fucus nodosus*,—is merely a pelagic variety of that variable plant?"—*Harvey*, *Manual of the British Algæ*. (1841.) Introduction, pp. xvi. xvii.

My friend and colleague, Dr. Joseph Hooker, who has had great opportunities of studying the gulf-weed, believes with Dr. Harvey, [illegible] *bacciferum* is an abnormal condition of *Sargassum vulgare*. Now [illegible] plant growing on rocks with a very limited vertical [illegible] as *Sargassum bacciferum* in the gulf-weed [illegible] *ancient line of coast on which it originated* [illegible]

from the old,and favours the notion that the coast-line of a post-miocene European land would be somewhere in the central Atlantic, about the position of the great Fucus Bank. The probability of the ancient existence of such a land is further borne out by the fact that the floras of the groups of islands between the gulf-weed bank and the mainland of the Old World are all members of *one* flora, itself a member of the *Mediterranean type*, and only peculiar inasmuch as certain endemic species are present, many of which are common to the Azores, Madeira and the Canaries.

Having broached these views at the late Cambridge meeting of the British Association, I have had an opportunity of hearing and considering such objections as have been offered against them. Such as have been offered against the premises assumed, are sufficiently met by the preliminary observations on specific centres, which are also equally applicable to a proposition which has been made to account for the peculiarities of the British floras, by transmutation from marine into terrestrial species within given areas, though a knowledge of the submarine vegetation of the areas in question would have prevented such hypothesis ever having been broached. A more serious objection is that which asserts that a more extended view of the distribution of animals and plants will, so far from supporting, offer numerous difficulties to the theory which I have brought forward to account for the origin of our British fauna and flora. These, however, I have well considered, and have not as yet found any which at all invalidate my views, but, on the contrary, to render probable their general application. Whilst it is very probable that in the present state of the inquiry—its infancy, in fact—there are many of my data insecure and likely to require considerable modification hereafter, the great leading principle, I firmly believe, will stand the strictest investigation, and prove as true when tested by an appeal to the distribution of organized beings, as well fossil as recent, over the whole globe—as well during the several geological epochs of ancient times as in that in which we live, as it appears to be when applied to the limited area under consideration.

My main position may be stated in the abstract, as follows:—

The specific identity, to any extent, of the flora and fauna of one area with those of another, depends on both areas forming, or having formed, part of the same specific centre, or on their having derived their animal and vegetable population by transmission, through migration, over continuous or closely contiguous land, aided, in the case of alpine floras, by transportation on floating masses of ice.

The question of the general origin of alpine floras and faunas is, perhaps, the most important inquiry which such a position can affect, and may be regarded, in a great measure, as a fair test of its truth. If the

view I have put forward respecting the origin of the flora of the British mountains be true—and every geological and botanical probability, so far as that area is concerned, favours it—then must we endeavour to find some more plausible cause than any yet shown, for the presence of numerous species of plants, and of some animals, on the higher parts of alpine ranges in Europe and Asia, specifically identical with animals and plants indigenous in regions very far north, and not found in the intermediate lowlands. Tournefort first remarked, and Humboldt, the great organizer of the science of natural-history geography, demonstrated, that zones of elevation on mountains correspond to parallels of latitude, the higher with the more northern or southern, as the case might be. It is well known, that this correspondence is recognised in the general *facies* of the flora and fauna, dependent on generic correspondences, specific representations, and, in some cases, specific identities. But when announcing and illustrating the law that climatal zones of animal and vegetable life are mutually repeated or represented by elevation and latitude, naturalists have not hitherto sufficiently (if at all) distinguished between the evidence of that law, as exhibited by *representative* species and by *identical*. In reality, the former *essentially* depend on the law, the latter being an *accident* not necessarily dependent upon it, and which has hitherto not been accounted for. In the case of the alpine flora of Britain, the evidence of the activity of the law and the influence of the accident are inseparable, the law being maintained by a transported flora, for the transmission of which, I have shown, we can account by an appeal to unquestionable geological events. In the case of the Alps and Carpathians, and some other mountain ranges, we find the law maintained partly by a representative flora, special in its region, *i. e.*, by specific centres of their own, and partly by an assemblage more or less limited in the several ranges of identical species, these latter in several cases so numerous that ordinary modes of transportation now in action can no more account for their presence than they can for the presence of a Norwegian flora on the British mountains. Now, I am prepared to maintain, that the same means which introduced a subarctic (now mountain) flora into Britain, acting at the same epoch, originated the identity, so far as it goes, of the alpine floras of middle Europe and central Asia. For now that we know the vast area swept by the glacial sea, including almost the whole of central and northern Europe, and belted by land, since greatly uplifted, which then presented to the water's edge those climatal conditions for which a subarctic flora—destined to become Alpine—was specially organized, the difficulty of deriving such a flora from its parent north, and of diffusing it over the snowy hills bounding this glacial ocean, vanishes, and the presence of identical species at such distant points remains no longer a mystery. More-

over, when we consider that the greater part of the northern hemisphere was under such climatal conditions during the epoch referred to, the undoubted evidences of which have been made known in Europe by numerous British and Continental observers, on the bounds of Asia by Sir Roderick Murchison, in America by Mr. Lyell, Mr. Logan, Captain Bayfield, and others; and that the botanical (and zoological as well) region essentially northern and alpine, designated by Professor Schouw that "of saxifrages and mosses," and first in his classification, exists now only on the flanks of the great area which suffered such conditions; and that, though similar conditions reappear, the relationship of alpine and Arctic vegetation in the southern hemisphere with that in the northern is entirely maintained by *representative* and not by identical species; (the representation, too, being in great part generic, and not specific), the general truth of my explanation of the origin of alpine floras, including identical species, becomes so strong, that the view proposed acquires fair claims to be ranked as a theory, and not considered merely a convenient or bold hypothesis.

Assuming as well founded the origin and general diffusion during the glacial epoch of a flora and fauna of subarctic and Alpine type throughout the northern and central regions of the old world, an important *corollary* follows, respecting the relative antiquity of the flora and fauna now general throughout the British Isles (which I have termed the Germanic), derived by migration over the upheaved bed of the glacial sea, from the central regions of Europe, viz.,—that the Germanic fauna and flora, equivalent to a part of the second botanical province in Professor Schouw's arrangement, not only migrated at a later epoch, but also *originated later in time* than the Scandinavian flora, which now clothes the summits of our mountains.

If the views I have offered respecting the origin and distribution of our terrestrial fauna and flora be correct, we might expect to find evidence in their favour when we inquire into the distribution of the marine plants and animals now inhabiting the British Seas. Especially ought we to discover important facts bearing upon the soundness of the propositions respecting the origin of our alpine flora, for we have already seen that the conversion from a general flora, clothing most parts of the area as were then above water, into a limited assemblage of plants almost all confined to the mountain summits, was owing to an elevatory action by which the bed, or a great part of the bed of the glacial sea, was left high and dry. The remains of that ancient sea bottom, in the form of stratified and unstratified masses of clay, sand, and gravel, often including large boulders, and presenting in many places considerable thickness and superficial extent, are to be met with in many parts

of Great Britain and Ireland. In those beds we find fossils, and as these fossils are the remains of animals coeval, if my theory be true, with the existing flora of our mountains, an examination of them ought to afford a good test of its correctness.

Before, however, inquiring into this matter, let us take a general glance at the botanical and zoological features presented by the British seas. A correct knowledge of these, and even in certain departments of their details, will be absolutely necessary to any geologist who hereafter may engage in one of the most interesting inquiries in British geology, as yet but very imperfectly handled,—the history of the northern drift and boulder clays.

The marine flora is of much less importance, as bearing upon these inquiries, than our marine fauna. For as almost all (*Zostera* and *Zanichellia* are exceptions) of the plants inhabiting our seas are cryptogamic, and marine cryptogamia seem to be far more widely diffusable, owing to the organization, transportability, and persistent vitality of their germs (spores)—and also to the capacity of cryptogamic plants to endure great vicissitudes of climatal conditions—their zones of distribution are not nearly so definite as those of most seed-producing plants, and a great number of species are cosmopolitan. Thus there are species of *Ulva*, *Enteromorpha*, *Codium*, and other genera, which seem to have an universal distribution, extending from pole to pole, and diffused through both hemispheres. As a general rule, however, the higher the algue, the more limited in distribution; and well marked, though wide algological regions have thus been traced out by botanists. The observations of Lamouroux, that the diffusion of algæ is determined by lines of coast and depth of water, shows that even their distribution has been mainly determined by geological events; and ere long, when it shall have been studied with reference to the latter, I do not doubt we shall gain new and unexpected information respecting the causes which have arranged them in the sea as they now are. From the researches of Dr. Greville, Mr. Harvey, Mrs. Griffith, and other British algologists, it appears that our marine vegetation presents at least two well-marked types; a southern and a northern, both perhaps admitting of minor subdivisions. Thus the genera *Padina* and *Halyseris* do not range further north than the south coast of England, and are met with only in few localities there; and the genera *Cystoseira*, *Sporochnus*, *Elaionema*, *Cutleria*, certain species of *Dictyota*, *Sphacelaria*, *Mesogloia*, *Rhodomenia* (*R. bifida*, *R. jubata*), and *Gigartina*, all aid in marking out a southern region, which includes the British Channel, and part of the east coast, the Bristol Channel and the south and west of Ireland. The absence of southern species, the greater abundance and luxuriance of northern forms, and the presence of such fuci as *Odon-*

thalia dentata, Rhodomela cristata and *lycopodioides*, and *Fucus Mackaii*, in like manner characterise a northern flora on the coasts of Scotland and of the north of England and Ireland.*

The fauna of our seas, like the flora, presents distinct northern and southern relations. These are especially manifest among the Invertebrate animals, and also among the fishes. The few marine *Mammalia* included in the British list, are mostly derived from northern regions though some, as *Phoca vitulina* and *Delphinus phocæna* are constant and characteristic residents. *Phoca barbata* and *Delphinus melas* may be regarded as representatives of a *Boreal* type and *Trichechus rosmarus*, *Delphinus albicans*, *Monodon monoceros*, *Balæna mysticetus* and *Balænoptera boops* and *rostrata* as *arctic* forms, wandering to the limits of their range. Some of the larger Cetacea appear to have been more frequent visitors to our shores anciently—even during historical times—than now. The marine Reptilia represented by *Sphargis coriacea* and *Chelonia imbricata* are members of a southern type, and visitants from an opposite direction to that whence we have obtained our aquatic mammals.

The distribution of our native marine fishes exhibits distinctly four types, of which two, a northern and a southern, belong to great ichthyological provinces, the bounds of which approach, but can scarcely be said to meet in our seas—and two, a British and an oceanic, the former including those species either peculiar to or chiefly developed in the British Seas, and of which the Irish Sea may be regarded as the *centre* or *capital*, and the latter of pelagic forms occasionally or frequently visiting our shores in common with most of the coasts of the north Atlantic.

The occasional visitants of the south-western coasts of England indicate that the southernmost parts of our islands are not far from the northern bounds of the great province of south-European fishes, a region of which the coasts of the Peninsula may be regarded as the centre, and the Mediterranean as in a great measure an extension eastwards. To this province belong many of our rarities, such as *Serranus cabrilla*, *Serranus gigas*, *Mullus barbatus*, *Pagrus vulgaris*, *Pagellus erythrina*, *Dentex vulgaris*, *Labrus iulus*, *Muræna helena* and *Ophidion imbarbe*.

* For details on the Marine Botany of Britain, consult Mr. Harvey's 'Manual of British Algæ.' The deficiency of such marine Algæ as are most characteristic of provinces on the north-east coast of Britain, is strikingly shown in the account given by Dr. Dickie, of King's College, Aberdeen, in his paper 'On the Marine Algæ of the vicinity of Aberdeen,' in the 'Annals of Natural History for August, 1844.' Out of 80 British species of *Melanospermeæ*, 46 are absent from the coast examined. "Among the *Fucoideæ*, the total absence of *Cystoseira* will be observed, and scarcely one-half of the British species occur; of *Laminariæ*, scarcely one-half; of *Sporochnoideæ*, only one-third; the two species of *Desmarestiæ* being generally distributed in Britain. There is also a great deficiency in the *Dictyoteæ*, *Cutleriæ*, *Halyseris*, *Padina*, *Dictyotæ*, and *Striaria*, being totally absent. Of *Ectocarpeæ*, about one-half of the British species are found, and three out of five *Chordariæ*."—*Annals*, vol. iv. p. 112.

Such can scarcely be regarded as true members even of our southernmost ichthyological fauna, of which are rather characteristic *Zeus aper*, *Trigla pini*, *Pagellus centrodontus*, *Cepola rubescens*, *Atherina presbyter*, *Blennius ocellaris*, *Cantharus griseus*, *Trygon pastinaca* and *Clupea pilchardus*; the last, though found on most parts of our coast, being only prevalent in the south-west.

In like manner our northernmost ichthyological province includes at its extremity occasional visitants which there reach the south-eastern limit of their range, as *Cottus quadricornis*, *Scorpæna Norvegica*, *Gymnetrus arcticus*, *Scymnus borealis*, *Chimæra monstrosa* and *Brosmus vulgaris*; the two latter are constant and the last an abundant inhabitant of the Zetland Seas. Certain species also, which though they range throughout our seas, are only abundant in the north, may be regarded as true members of this province—as *Anarrhicus lupus*, *Merlangus carbonarius*, *Cyclopterus lumpus* and *Myxine glutinosa*, and even the cod (*Gadus Morrhua*), and the herring (*Clupea harengus*).

The assemblage of fishes, of which the British Seas may be regarded as the centre, is partly composed of species which are not known elsewhere, and therefore essentially of a *British type* and partly of such as are characteristic of the seas bounding the shores of the *central* portion of Western Europe, and which may be styled the Celtic region. That great extension of sub-marine land surrounding the British Isles, a map of which has been given by Sir Henry De la Beche, in his 'Researches in Theoretical Geology' (where the important bearing of such a tract on many geological phenomena is admirably explained), may be regarded as the true country of the Celtic sub-marine fauna, of which such fishes form a part. *Leptocephalus Morrisii*, *Lepadogaster cornubiensis*, *Liparis Montagui*, *Clupea alba*, and *Raniceps trifurcatus* are examples of the first or British division of this type, whilst a host of species, including *Trigla gurnhardus*, *Cottus bubalis*, *Aspidophorus cataphractus*, *Scomber scomber*, *Blennius pholis*, *Crenilabrus tinca*, *Merluchius vulgaris*, *Lota molva*, *Solea vulgaris*, *Pleuronectes maximus* and *rhombus*, *Anguilla conger*, *Ammodytes tobianus* and *lancea* are well-known members of the second.

To the oceanic type belong such of our occasional visitors as have very wide ranges, as *Naucrates ductor* (the pilot-fish), *Echineis remora* (the sucking fish), *Trichiurus leptura*, *Xiphias gladius* (the sword fish), *Scomber pelamys* (the bonito), and many of our sharks.

The marine *Articulata* of the British Seas have been so little studied, so far as their distribution is concerned, that it is difficult to give even the slightest sketch of it. Materials, however, are gradually accumulating, and so far as the *Crustacea* are concerned—the division most important to the geologists, seeing that their remains are often preserved in

upheaved strata—this defect will be in a great measure remedied by the completion of the 'History of British Crustacea,' by Professor Bell, now in the course of publication. Before the appearance of that work Mr. W. Thompson's 'Report on the Irish Fauna' was the only sound authority. The 'Catalogue of British Annellides' lately published in the 'Annals of Natural History,' by Dr. Johnston, has given us a firm basis on which to found our researches in that difficult department: but the distribution of European Annellides—a most interesting subject—is at present a blank in zoological science. We have every reason to believe that both marine worms and Crustacea exhibit a distribution on our shores very correspondent to that ascribed to the fishes. Thus among the higher *Crustacea* an extreme southern type is indicated by such forms as *Macropodia tenuirostris* and *Pisa gibsii*, and certain other species confined as British to the south-western parts of the Channel:—a *southern* British type by *Maia squinado*, *Pinnotheres pinnæ*, *Achæus cranchii* and *Lithodes maia*:—a Celtic and *central* British type by *Macropodia phalangium*, *Inachus Dorsettensis*, *Hyas araneus*, *Portumnus variegatus*, *Pinnotheres pisum* and species of *Ebalia* and *Pagurus*—a *northern*, by *Nephrops norvegicus*, *Porcellana platycheles*, and species of *Alauna* and *Cuma*—and an *oceanic* or general North Atlantic, probably by *Pagurus Bernhardus*, *Homerus vulgaris* and *Palæmon serratus*. Among the *Cirrhopeda* too are found *Balanus scoticus*—important, as will be seen hereafter, in a geological point of view—characteristic of the northern portion of our seas, and *Acasta Montagui* of the southern, whilst the pedunculated forms are, with the exception of *Scalpellum vulgare*, either oceanic and prevalent on the ocean side of our islands, or species introduced by their habits of adhering to the sides of ships and to floating wood. The marine shell-constructing *Annelida* present some peculiarities of distribution worthy of notice by geologists, such as the prevalence of *Serpula serrulata* in the deeper regions of the northern provinces and the constant occurrence of species of *Ditrupa* at great depths in several parts of our seas far from land.

Our knowledge of the species and distribution of the British Mollusca is very complete, and sufficient to enable us to apply it to the elucidation of geological problems with safety and effect. When we consider the perfect state in which the testaceous species are preserved, and the facility of specific identification afforded by their shells, this becomes of great importance. In all questions respecting the age of sedimentary strata, the evidence afforded by the fossilized remains of mollusks must, from its completeness, always take precedence of that derived from any other class of animals. Though our native existing species have been well determined, there is no one work upon them to which the geologist can be referred with safety, nor any comprehensive essay as yet pub-

lished on their distribution. Valuable materials have, however, been collected in the larger works of Montagu, Turton, and Fleming, and in many essays on local faunæ, among which, the Report of Mr. W. Thompson 'On the Irish Invertebrata,' published in the Transactions of the British Association for 1843, and prepared at the request of that body, is by far the most important. The following sketch of the distribution of marine Mollusca on the British shores, is offered as a brief summary of the results, chiefly of my own observations.

I. In the southern part of the British Channel, we find certain species which have there the northernmost limits of their range. Such are *Haliotis tuberculata*, which, abundant in the Channel Isles, is not indigenous on our own shores, *Emarginula rosea*, occasionally taken on the south coast of England, but frequent on the coast of Guernsey, *Truncatella Montagui*, *Rissoa Bryerea*, *denticulata* and *calathisca*, *Calyptrea sinensis*, *Donax complanata*, *Lucina pisiformis*, *Galeomma Turtoni*, *Pandora rostrata*, and *Lithodomus lithophagus*. These species mark the bounds of a fauna which can scarcely be regarded as within our limits.

II. Some of them, however, are occasionally found alive on our southern shores, and on the south and south-west of Ireland, associated with a number of species which constitute a well-marked *South British* type. Such are *Avicula atlantica*, *Modiola Gibsii*, *Venus verrucosa*, *aurea* and *chione*, *Venerupis irus*, *Arca lactea*, *Cardium tuberculatum*, *Pholas dactylus* and *lamellata*, *Volva patula*, *Pleurotoma gracilis*, *Trochus exasperatus*, *striatus* and *crassus*, *Adeorbis subcarinatus*, *Rissoa striatula* and *auricularis*, and *Pollia minima*. This fauna stretches far up on the coast of Ireland, occupies St. George's Channel, having its northern limits about the line of Cardigan Bay, and is generally distributed through the English Channel, even to the entrance of the German Ocean.

III. There are certain species very generally diffused throughout the seas and shores of the British Isles, and which range generally through the European Seas, or at least along the coasts of Western Europe, from Norway to the south of Spain. Such constitute an *European* type. Such are: *Turritella terebra*, many *Rissoæ* (as, *R. striata*, *cingilla*, *parva*, *interrupta*, *ventricosa*, *fulva*), *Odostomia plicata*, *Trochus magus*, *ziziphinus*, *tumidus*, *cinerarius*, several *Pleurotomæ*, *Aporrhais pespelecani*, *Cypræa Europæa*, *Tornatella fasciata*, *Natica Alderi*, *Dentalium entalis*, *Patella vulgata*, *Emarginula fissura*, *Chiton fascicularis*, *Capulus hungaricus*, *Ostrea edulis ? Pecten opercularis*, *Nucula nuclea*, *Modiola marmorata*, *Cardium edule*, *lævigatum* and *echinatum*, *Donax trunculus*, *Tellina donacina*, *tenuis*, and *fabula*, *Abra Boysii*, *Mactra stultorum*, *Kellia suborbicularis*, *Artemis exoleta* and *lincta*, *Venus ovata*, *fasciata*, and *gallina*, *Pullastra virginea*, *Corbula nucleus*, and *Psammobia tellinella*.

Most of the above-named species are very prolific, several being gregarious. An important point respecting them is the fact, *that they are all confined to the eastern coasts of the Atlantic.* The application of this fact will be seen hereafter.

IV. As plentiful in our seas as the species constituting the *European* type are many forms, the relations of which are rather northern than southern, but their chief development within and around our area. These constitute the *Celtic type.* Such are, *Bulla lignaria, Skenea depressa, Littorina littorea, rudis,* and *neritoides;* several species of *Lacuna, Nassa reticulata* and *macula, Purpura lapillus, Buccinum undatum, Fusus antiquus, Triton erinaceus, Natica monilifera, Patella pellucida,* and *lævis, Lottia virginea, Chiton marginatus, Pecten maximus, Pectunculus pilosus, Modiola vulgaris, Abra prismatica, Mactra solida,* and *subtruncata, Astarte danmoniensis, Venus cassina, Pullastra vulgaris, Pandora obtusa, Mya truncata* and *arenaria, Solen siliqua* and *ensis,* and *Saxicava rugosa.* Several of these are common to the coasts of Europe and of North America. Such species have invariably a continued range north of Britain, and with two or three exceptions cease before they reach the Mediterranean.

V. In the British Seas are a number of species not known elsewhere, or else very rare on other coasts. These are mostly found in the Irish Sea, which appears to have been the centre from which they have radiated. They constitute a peculiarly British type: *Chemnitzia fulvocincta,* and some allied species; several *Rissoæ* and *Odostomiæ, Skenea serpuloides* and *divisa, Trochus umbilicatus, Montacuti,* and *millegranus, Scalaria Turtoni* and *Trevelyana, Velutina otis,* and *Natica Montagui,* may be cited as examples; and such bivalves as *Pecten sinuosus* and *obsoletus.*

VI. In Dr. Fleming's History of British Animals—a work the original merits of which have scarcely yet been done justice to—the range of a great number of species of British Mollusca is summarily stated as "from Devon to Zetland." Many of the forms thus noted, are rarely, if ever, found in the Irish Sea or in the German Ocean. Nevertheless, the note of range is quite true, and founded on the personal observations of Dr. Fleming in the Zetland Isles and north coast of Scotland, as compared with those of Montagu on the south coast of England. The Mollusca, and other animals alluded to, are not generally distributed through the British Seas, and are mostly of southern origin (or members of the South European fauna). They are not grouped in patches far apart, but have a continuous distribution, which, commencing at the south-western shores of England, is extended across the southern part of St. George's Channel, is continued along the west coast of Ireland, round to the Hebridean Isles, and even northwards to the Zetland Seas. Thus, the species, among which are

many of the forms common to the British and Mediterranean Seas, are mingled in their course with forms characteristic of the Celtic, Boreal, and sub-Arctic regions; and nothing but the most minute examination and the active employment of the dredge, and registering of its contents, could have cleared up the confusion which this peculiarity in the distribution of the fauna of our western shores, bordering the Atlantic, threatened to introduce into all our calculations.

This portion of our fauna, which for convenience I will term the *Atlantic* type, to distinguish it from the *Oceanic*, we see exemplified in such species as, *Bulla cranchii*, *Eulima polita*, *Eulima subulata*, *Littorina cærulescens*, *Rissoa cimex*, *R. costata*, *Scalaria Treveliana*, and *clathratulus*, *Cerithium lima*, *Triphoris adversus*, *Pleurotoma attenuata*, *linearis*, *purpurea*, *gracilis*, *Erato lævis*, *Terebratula caput serpentis?* *Pecten lævis*, *Lima tenera?* *Lima subauriculata*, *Arca tetragona*, *Cardium elongatum?* *Lucina spinifera*, *Circe minima*, *Pullastra decussata*, *Solenecurtus candidus*, and *antiquatus*, *Psammobia florida* (*vespertina*, Turt. non *Lam.*), and *Gastrochæna pholadia*.

VII. On the same coasts with these species are taken the mollusks of an *Oceanic type*, mostly occasionally visitors drifted hither by storms from the west and south. Such are *Spirula Peronii*, which has several times been cast up on the west coast of Ireland, *Ianthina communis*, *nitens*, and *exigua*, *Hyalæa trispinosa*, and possibly *Peracle Flemingii*. With these we may expect some day to find other species of *Pteropoda*. The various species of *Anatifa* among the cirrhipeds, and of *Velella* and *Diphyes* among our Medusæ, included in our fauna, are members of the same type.

VIII. The coasts of Scotland, and the neighbouring parts of England and Ireland furnish the cabinets of conchologists with many species which are very rare or almost unknown on the English shores. Some of these are confined to the east coast, some to the west, but the greater number are common to both. Such are, *Pecten niveus*, *nebulosus* and *striatus*, *Nucula tenuis*, *minuta* and *pygmæa*, *Crenella decussata*, *Modiola nigra*, *Cardium Löveni*, *Abra intermedia*, *Astarte elliptica* and *compressa*, *Cyprina islandica*—found everywhere on our shores, but abundant only in the north—several species of *Neæra*, *Panopæa arctica*, *Margarita communis* and *striata*, *Trichotropis borealis*, *Fusus Barvicensis*, *Bamfius*, and *Norvegicus*, *Velutina lævigata* and *ovata*, *Natica helicoides*, *Lottia ancyloides*, *testudinaria* and *fulva*, *Emarginula crassa*, *Cemoria noachina*, *Chiton Hanleyi*, *Crania Norvegica*, and *Terebratula caput serpentis*. Most of these species are found also on the Scandinavian shores, and several of them are common to the North American and North European Seas. They constitute my *Boreal type*, the province of which extends northwards, from the northern shores of the Isle of Man and Ireland, on

the one side, and from the central portion of the German Ocean on the other.

IX. Found rarely south of the most northern of our seas, and for the most part rare even there, are certain species which mark the near approach of an Arctic or sub-Arctic province. Such are, *Margarita undulata*, *Natica groenlandica*, *Fusus albus* and *Sabini*, *Buccinum Donovani*, *Astarte borealis*, and *Terebratula cranium*. They are associated with zoophytes of equally Arctic character. Many of the species enumerated under the last type are much more abundant, and finer, in the northernmost province, of which they are truly members—their distribution southwards being occasional and in isolated patches, the nature of which I shall hereafter explain.

Our native *Radiata* have a similar distribution with the *Mollusca*, though, perhaps—owing to the great powers of locomotion which many of them possess, either in their perfect or else in their larva state—not so well marked. The coral *Turbinolia milletiana* (discovered by Mr. MacAndrew, *alive*, off the Cornish coast, hitherto known only as fossil) and the *Echinus lividus*, *Thalassema Neptuni*, and *Syrinx nudus*, are examples of the southernmost types. *Comatula rosacea*, *Ophiura texturata* and *albida*, *Ophiocoma rosula* and *neglecta*, *Uraster glacialis*, *Palmipes membranaceus*, *Asterina gibbosa*, *Asterias aurantiaca*, *Echinocyamus pusillus*, *Spatangus purpureus*, *Cucumaria pentactes*, and *Syrinx nudus*, among the Echinodermata, and *Pennatula phosphorea*, *Alcyonium digitatum*, *Actinea effœta*, *Laomedea gelatinosa*, *Sertularia pumila* and many hydroid zoophytes, *Cellepora pumicosa*, *Tubulipora serpens*, and many ascidioid zoophytes, are representatives of the third or European type. So also are such Medusæ as *Aurelia aurita* and *granulata*.

The *Celtic* type is seen in *Uraster rubens*, *Solaster papposa*, *Echinus sphæra* and *miliaris*, *Amphidetus cordatus* and *roseus*, *Thyone papillosa* and *Echiurus vulgaris*, *Actinea mesembryanthemum*, *senilis* and *dianthus*, *Flustra foliacea*, *Antennularia antennina*, *Plumularia falcata*, and many *Sertulariæ* and other hydroid and ascidioid zoophytes.

The *British* type is represented by *Ophiocoma brachiata*, and *minuta*, *Uraster hispida*, *Syrinx Harveii*, several corneous zoophytes, as, *Thuaria articulata* and *Plumularia myriophyllum*, *Actinea bellis*, *Anthea tuediæ*, *Capnea sanguinea*, *Iluanthus scoticus?* *Cellepora Skenei*, and many other ascidioid zoophytes. I doubt whether any of our *Medusæ* come properly under this head.

The *Atlantic* type is represented by certain zoophytes, among which are *Carophyllia Smithii*, *Plumularia pennatula*, and *Eschara foliacea*.

The *Oceanic* type is instanced by such Medusæ as *Velella* and *Diphyes*, occasional visitants of our western shores.

The *Boreal* type has numerous members among the Radiata.

Echinoderms, *Ophiocoma granulata* and *bellis*, *Goniaster pulvillus* (*Templetoni*), *Echinus Flemingii?* *Brissus lyrifer*, *Psolus phantapus*, *Cucumaria frondosa*, *Thyone raphanus*, and other *Holothuriadæ*, are good examples; as are the species of *Beroë* and *Alcinoë*, among the *Acalephæ*. Of zoophytes *Virgularia mirabilis*, and other species frequent only in the northern coasts of Britain, belong to this type, as also do several sponges.

The *sub-Arctic* type is well marked in the Zetland Seas by the presence of several Radiata which do not range farther south; such as, *Echinus neglectus*, *Cidaris papillata*, *Echinarachneus placenta?* *Lucernaria fascicularis*, *Actinea intestinalis*, *Oculina prolifera*, *Primnoa lepadifera*, *Astrophyton scutatum*, *Priapulus caudatus*, *Corymorpha nutans*, *Flustra setacea*, and *Tethya cranium*.

I have dwelt thus fully on the distribution, *horizontally*, of British marine animals, because a knowledge of it is of the *greatest importance* to the geologist who directs his attention to the phenomena presented by tertiary strata, not only within our own area, but throughout the northern hemisphere, and because the subject is one of which there is no connected view presented in any published work, whilst even the details of many parts are either not in print or scattered through many books, journals, and memoirs. In the first section of this essay, it was not necessary to do so when our flora and terrestrial fauna were concerned, as (especially of the former) the details are fully collected and combined in accessible and well-executed works. This is also the case with the marine vertebrata, but not as yet with the greater part of the invertebrate animals of our seas, whose remains, as will be seen hereafter, furnish an invaluable clue to the history of conditions, climatal changes, and changes in the distribution of submarine life, which preceded the historical epoch, and organized, as it were, the present state of things.

The ancient history of this fauna—so far as the area under discussion is concerned—may be clearly made out. The most ancient traces of existing species still inhabiting the British Seas are probably to be found as far back as the cretaceous epoch, when *Terebratula caput serpentis*, certain existing foraminifera (identified by Ehrenberg), and possibly some deep-sea corals lived under similar conditions of depth with those which now determine their distribution. About these, however, there may still be doubts, and even about most or all of the forms identified with existing British species, found in strata of the eocene period, when the assemblage of inorganic and organic phenomena within our area was such as cannot be compared with that presented by it at present, though closely approximating the state of things in certain regions nearer the equator. The close of the eocene period was probably marked by such a change in the disposition of land and water in the

region of western Europe, as to cause an almost entire disappearance of the then marine fauna.

In the lowest, or coralline crags, however, we have presented decided relations between our existing marine fauna and that which then occupied the area of the south-west of England. The number and state of preservation of the Mollusca, Radiata, Cirrhipeda and testaceous Annellida, found in that formation, enable a very complete comparison to be instituted; and the elaborate catalogues of Mr. Searles Wood, drawn up with the greatest care and judgment, furnish materials for our inquiry, such as are not often at the disposal of the palæontologist. From Mr. Wood's researches, it appears that out of above 340 species of testaceous mollusks, found in the coralline crag, 73 are now known living in the British seas; among these are 23 which are found fossil in the northern drift, or *Newer Pliocene* beds of Britain. With the exception of *Trichotropis borealis* and *Lottia virginea*, both northern forms, the remainder consists of such British species as chiefly range south of Britain, in almost every case extending to the Mediterranean. The coralline crag mollusks not now living in the British Seas are either extinct forms, or species now commencing their northernmost range south of Britain: with them is associated *Cancellaria costellifer*, only known fossil in Europe, but still living on the northern shores of the United States. The zoophytes of the coralline crag present similar phenomena. Out of 57 species most carefully examined by Mr. Searles Wood, 18 or 19 are existing British forms: these are associated with polypidoms of a more southern character, including species of *Balanophyllia, Cladocora, Fascicularia, Theonoa, Hornera, Lunulites, Fungia*, &c., of which we have now no representatives in our seas.

In the Red Crag there are about 260 species of testacea, out of which 60 are now known alive in the British Seas, a larger proportion than in the coralline. The increase, too, of northern forms, is very marked, 41 out of the 60 being species which occur fossil in the "northern drift." Of these, 19 are common to the coasts of Britain and America, and are associated with four species now known living only in the Arctic or Boreal-American Seas. The American *Cancellaria* also lived in our area during this epoch. All the British species found in the red crag, which are not known in the preceding formation, are of northern origin. The rest of the red crag molluscan fauna is made up of species either southern or extinct. The number of zoophytes has greatly diminished, 25 species only having been observed, 14 of which are existing in the British Seas. The number of southern forms has also greatly diminished.

Among the comparatively few marine shells recorded as fossils of the Norwich or mammaliferous crag, we find some British or northern

species not previously met with, as *Tellina fabula* and *solidula*, *Donax trunculus*, *Astarte borealis*, and *Murex erinaceus*. The data are, however, not sufficiently complete to enable us to say more than that the fauna of the epoch during which that deposit was formed presented general features of a decidedly mixed Celtic and northern character.

Putting the mammaliferous crag aside, it is evident that the "coralline" and "red" crags afford clear indications of a state of things in the seas in which they were formed, very distinct from that now presented by the seas surrounding the British Isles. Mr. Searles Wood's reference of the coralline crag fauna to a type comparable with that now presented by the assemblage of marine animals in the Mediterranean, or on the coast of Portugal, appears to me to come very near the true state of the case; and his observations on the subject, in the ninth volume of the Annals of Natural History, are well worthy the attention of geologists. The epoch of the red crag was evidently marked by a new set of conditions which materially changed the character of the fauna. The key to the problem presented by these must be sought for in the *zoological* phenomena exhibited by the remarkable strata known under the names of "Boulder clay," "Arctic or northern drift," "Pleistocene," or sometimes "Newer Pleiocene," and in some authors "post-tertiary," including (in part) the "Till" deposits, which for convenience I shall henceforth mention as *glacial*, or as *beds of the glacial epoch*. My chief purpose in drawing up this essay, is to assist in the elucidation of that most interesting and important formation—one which will engage much of the attention of the geological surveyors —by exhibiting the nature and value of the evidence afforded by organic remains found in those beds, and the bearing of that evidence on the history of animated nature within the area under examination by the Survey, immediately before and subsequent to their formation. This evidence has not hitherto been put in a tangible form, nor has it been fully appreciated except by very few geologists, of whom Mr. Smith, of Jordan Hill, was the first to endeavour *inductively* to work out in detail the many problems it involves, and to impress upon the geological world the variety and interest of the palæontological phenomena presented by the *glacial beds* in the northern districts of Britain and Ireland. There is now a great mass of evidence existing, scattered through books or known to a few and as yet unpublished—sufficient to enable us to present well-grounded generalizations.

Exactly a century ago, the attention of the greatest of modern naturalists was arrested by the zoological phenomena presented by the glacial beds in Sweden. In the course of his journey through Wast-Gota, in 1746, Linnæus visited Uddevalla, the very locality destined long after, to furnish Mr. Lyell with part of the materials for his celebrated essay

on the 'Rise of Land in Sweden.'* The account of Linnæus's journey was published (in Swedish) in 1747. The descriptions and figures of the Uddevalla fossils there given, appear to have escaped the notice of most subsequent writers. Professor Jameson, when noticing Mr. Lyell's paper in the 'Edinburgh New Philosophical Journal,' briefly directed attention to the observations of Linnæus. As they have not been referred to in any geological work with which I am acquainted, and as, from the accuracy of the information they contain, they must be regarded as among the most valuable of the published notes on the organic remains of the northern drift, as well as most interesting, on account of the time of their publication, and the man who recorded them, I avail myself of the kindness of my distinguished friend, Dr. R. G. Latham, to present a translation of the passage in the 'Wast-Gota Resa.'

"The shell hills (Skalbargĕn) are rightly reckoned amongst the greatest wonders of Bohuslaen; for they lie inland nearly a whole quarter of a mile, in some places, from the sea. These shell hills consist of periwinkles and bivalve shells (Snacke-och Muskle-skal), which are here assembled in such numbers, that one wonders how so many living beings existed on the earth. We visited Capell Hill, which lay a quarter of a mile beyond the southern Uddevalla Gate: then we went to Sammered, which lay nearly a quarter of a mile from the town, N.E. In both places were these shell-hills, especially and most markedly at Sammered. Here there were bare and hillocky ridges of gray stone, which, on the sides that front the town or the sea, where the bay was originally, bent in. The earth was slightly convex on the summits of the above-named hill, and made a curve; where the black mould, which was seldom more than a foot or a foot and a half deep, thinned off, the shell bed, which was two or three fathoms deep, underlaid it. Under this came in succession pure clay. No shells were seen above this stratum among the bare hill ridges. They stretched, however, altogether from the hill downwards under the black mould, often to the breadth of several gunshots. The shells lay clean and unchanged, with no addition of soil, only strewn over with a little gravel, such as is thrown up on the beaches. I sought carefully for all the sorts of shell fish that were found here, in order that I might determine from what world they came, or if the sea, even as the land, had changed its inhabitants."†

Linnæus then gives an enumeration of the species he found there, and figures the most remarkable. He notices the following: 1st. "Lepas quæ Balanus Uddevallensis."—Tab. v. fig. 1. This is our *Balanus scoticus.*

2nd. "Concha oblonga obtusa, sulcis transversis."—Tab. v. fig. 2. This is the large variety of the *Saxicava rugosa*, or *Saxicava sulcata.*

* Philosophical Transactions, for 1835.

† Linnæus, Wast-Gotha Resa, p. 197–98.

3rd. "Concha lævis, altera tantum parte clusilis, apophysi admodum prominente lataque prædita."—*Lister. Angli.*, 191, tab. v. fig. 36. The figure referred to in Lister, represents *Mya arenaria.*

4th. "Cochlea testa ovata, spiris quinque striatis fasciatis, aperturæ margine postero dilatato rotundato,—kupunge."—*Lister. Angli.*, 162, tab. iii. fig. 9. The figure referred to in Lister is that of *Littorina littorea.*

5th. "Concha Mytilus dicta." *Mytilus edulis.*

6th. "Cochlea spiris quinque utrinque producta striis acutis imbricatis."—Tab. v. fig. 6. This is the well-known and characteristic glacial fossil, *Fusus scalariformis*, which, since Linnæus's time, has been over and over again described and figured as new, under different names.

7th. "Concha Pecten dicta striis numerosissimis."—Table v. fig. 7. This is the *Pecten islandicus*, equally characteristic of these beds.

8th. "Cochlea spiris octo oblonga utrinque producta lineis duabus elevatis."—Tab. v. fig. 8. This is the subcárinated variety of *Fusus antiquus.*

9th. "Lepas concha anatifera transversim sulcata longitudinaliter striata."—Tab. v. fig. 9. This is *Balanus sulcatus.*

10. "Concha Pectunculus dicta (Fauna 1340)."

Sixty years after the observation of the fossils at Uddevalla, by Linnæus, they attracted the attention of the all-observing and philosophic Von Buch, who also noticed the occurrence of remains of existing testacea, in upheaved beds, in Norway. The presence of organic remains in similar beds in Scotland was noticed from time to time in the 'Memoirs of the Wernerian Society'—volumes which contain numerous valuable papers bearing upon the phenomena, both geological and zoological, of the glacial epoch. The Memoir of Mr. Lyell, on the Uddevalla deposits already referred to, published in 1836, gave a new impulse to the natural history part of the inquiry, from the invaluable list of fossils there given. The fruit of this in Britain, soon appeared in the researches of Mr. Smith, of Jordanhill, whose essays 'On the last Changes in the relative Levels of the Land and Sea in the British Islands,'* published in the Memoirs of the Wernerian Society, for 1837-38, will ever be esteemed as the foundation of a critical investigation of this most interesting subject, in Britain; and I feel proud to acknowledge that my first insight into "Newer Pliocene" geology was acquired through the instructions of that distinguished geologist, when accompanying him in one of his arduous but delightful journeys of investigation, in the Clyde district and north of Ireland. In the latter country, the phenomena of the drift had attracted the attention of many observers, among whom Dr. Scouler, Captain Portlock, Mr. Bryce, Mr. Griffith,

* In this memoir the history of the subject, especially so far as Scotland is concerned, is given so fully, that I have not thought it necessary to enumerate separate papers.

and Mr. Hamilton, had remarked on the fossils it contained. More recently, Mr. Oldham has given lists of Irish drift fossils. (For the papers referred to, see 'Proceedings of the Geological Society of Dublin.') But by far the most valuable data on the fossil contents of the drift in Ireland—data which for importance as bearing on the questions of its origin and history, can be compared only with those collected by Mr. Smith and Mr. Lyell—have been brought together during the researches of this survey, by Captain James, R.E., Chief Geologist for Ireland, and will be made known in detail in the course of the Survey Reports. In Wales the fossils of the glacial beds were made known by Mr. Trimmer, who has done much to thrown light on their history. To him we owe the information respecting the presence of existing shells on the summit of Moel Trefaen. Mr. Strickland has published in the Geological Proceedings valuable and *critical* observations on the fossils in the Isle of Man beds, further information on which has been recently communicated to the Geological Society by the Rev. R. G. Cumming. The observations of the Rev. Mr. Landsborough (Geol. Proc., vol. iii. p. 444), on pleistocene beds in the east of Scotland are very valuable, from their minute accuracy, a quality without which no natural-history statements on this subject can be received as of any authority. To complete this brief notice of the zoological literature of the drift, we may enumerate Capt. Bayfield's and Mr. Lyell's papers on the fossils in the Canadian beds, published in the Geological Transactions, the figures of drift fossils in Hisinger's 'Lethæa Suecica,' the papers of Dr. Forchhammer, the lists in Mr. Lyell's 'Travels in North America,' and the account of the fossils of the Russian drift, in Sir Roderic Murchison's great work on Russia, all containing data of the most accurate and valuable kind.

The British formations of the glacial epoch present themselves in the form of partially stratified, or often entirely unstratified beds of clay, marl, sand, and gravel, varying greatly in different localities; in many places charged with rounded boulders. Generally the clays and marls are inferior to the gravels and sands. They are to be met with in many parts of both east and west of Scotland; on both sides of the north of England; in Wales; through a great part of Ireland, and in the Isle of Man. These beds attain various degrees of thickness, forming in places cliffs more than 100 feet high, and occupying various elevations above the sea, from 0 to more than 1000 feet. When carefully examined, most of them are found to contain fossils, mostly marine testacea, usually scattered, rolled and broken, but in particular localities, entire and undisturbed, and presenting undoubted evidence of their having lived and died on the spot. In such places they are abundant; when rolled and broken, usually dispersed, and in no great plenty.

I have personally examined these fossils *in situ* in most of the localities

of the Clyde district, in company with, and under the guidance of Mr. Smith; in Wexford and Wicklow with Sir Henry De la Beche and Captain James, and alone in the Isle of Man, Cheshire, Lancashire, Anglesea, the north-east of England, the Forth district, and Caithness. For the statements herein made, I therefore hold myself responsible, and put them forth as the results of personal observation.

The total number of species of mollusca found in these beds in the British Isles, is about one hundred and twenty-four. With a few exceptions, they are all forms now existing in the British Seas. Nevertheless, they indicate a very different state of things from that now prevailing. As a whole, this fauna is very unprolific, both as to species and individuals, when compared with the preceding molluscan fauna of the red and coralline crags, or that now inhabiting our seas and shores. This comparative deficiency depends not on an imperfect state of our knowledge of the fossils in the glacial formations—on that point we now have ample evidence—but on some difference in the climatal conditions prevailing when those beds were deposited. Such a deficiency in species and individuals of the testaceous forms of mollusca, indicates, to the marine-zoologist, the probability of a state of climate colder than that prevailing in the same area at present. Thus the existing fauna of the Arctic Seas includes a much smaller number of testaceous mollusks than those of mid-European Seas, and the number of testacea in the latter is much less than in south-European and Mediterranean regions. It is not the latitude, but the temperature which determines these differences. Hence we find the number of testacea inhabiting the east coast of America, between the parallels of 45° and 50° N., where the waters are climatally influenced by the currents from the Arctic Seas, is much less than that assembled several degrees farther north on the coasts of Europe. In the following table, the number of testaceous mollusks of four well-ascertained faunas is contrasted with a summary of the testacea found fossil in the glacial formations of the British Isles. From it, it will be seen that the glacial molluscous fauna holds a numerical rank between

ORDERS OF MOLLUSCA.	Comparative Table of Testacea inhabiting				Fossil in British Glacial beds.
	The Mediterranean.	British Seas.	Seas of Massachusetts.	Greenland Seas.	
Cephalopoda, with shells .	1	1	1	..	..
Pteropoda	13	1	..	2	..
Nucleobranchiata . . .	6	1	..	..	..
Gasteropoda.	368	248	100	74	60
Lamellibranchiata . . .	200	210	83	44	63
Palliobranchiata. . . .	10	4	2	1	1
Total . .	598	465	186	121	124

such an assemblage of mollusks now inhabiting the coasts of Greenland (as determined by the researches of the late Dr. Möller,* and formerly by Otho Fabricius†), and such as may be found on the coasts of Massachusetts,‡—but approaching most nearly the former, and probably nearest that living on the coast of Labrador.

That the climate, under which the glacial animals lived, was colder, is borne out by an examination of the species themselves. We find the entire assemblage made up—1st, of species now living throughout the Celtic region in common with the Northern Seas, and scarcely ranging south of the British Seas; such are—

Modiola vulgaris.	*Fusus antiquus.*
Astarte compressa.	—— *corneus.*
—— *danmoniensis.*	*Lacuna vincta.*
Cyprina islandica.	*Nassa macula.*
Venus casina.	*Purpura lapillus.*
Mactra solida.	*Littorina littorea.*
Mya arenaria.	—— *rudis.*
—— *truncata.*	—— *neritoides.*
Leda minuta.	*Natica Alderi.*
Tellina depressa.	*Velutina lævigata.*
Pecten sinuosus,	*Trochus tumidus.*
Pleurotoma turricula.	*Patella pellucida.*
Buccinum undatum.	

2nd. Of species which range far south into the Lusitanian and Mediterranean regions, but which are most prolific in the Celtic and Northern Seas; as—

Cardium echinatum.	*Solen siliqua.*
—— *edule.*	*Anomia ephippium.*
—— *lævigatum.*	—— *aculeata.*
Venus fasciata.	*Ostrea edulis.*
Artemis exoleta.	*Pecten opercularis.*
Lucina flexuosa.	*Aporrhais pes-pelecani.*
Tellina solidula.	*Patella vulgata.*
Nucula nucleus.	*Dentalium entalis.*
Pectunculus pilosus.	*Turritella terebra.*
Pullastra decussata.	*Murex erinaceus.*
Saxicava rugosa.	*Emarginula fissuca.*
Solen ensis.	*Fissurella græca.*

3rd. Of species still existing in the British Seas, but confined to the

* Index Molluscorum Groenlandiæ. Hafniæ, 1842.

† Fauna Groenlandica, 1780.

‡ Gould's Invertebrata of Massachusetts, 1841.

northern portion of them, and mostly increasing in abundance of individuals as they approach towards the Arctic circle: such are,

Astarte borealis.
Astarte elliptica (gairensis).
Nucula tenuis.
Panopæa arctica.
Venus rugosa ?
Cemoria noachina.
Emarginula crassa.
Fusus barvicensis.
—— *bamfius.*
Pleurotoma reticulata.
Natica groenlandica.
Buccinum Humphreysianum.
Trichotropis borealis.

Leda pygmæa (fossil in the *newer pliocene* deposits of Italy, Germany, and Britain, but taken alive and abundantly, by Mr. MacAndrew, who dredged it in 1845, in the sound of Sleye, *where it is associated with boreal forms*) belongs to this assemblage. It is identical with *Nucula lenticula* of Möller, from Greenland.

4th. Of species now known, living only in European seas, north of Britain, or in the seas of Greenland and Boreal America, as

Astarte compressa, var. multi-costata.
Leda rostrata.
—— *hyperborea ?*
Tellina Groenlandiæ
——— *calcarea.*
Mya truncata, var. β.
Saxicava sulcata.
Pecten Islandicus.
Terebratula psittacea.
Fusus cinereus.
—— *scalariformis.*
—— *Fabricii*
Littorina expansa.
Margarita inflata.
Velutina undata.
Natica clausa.

5. Of species not now known existing, and unknown fossil in previous deposits.

Fusus allied to *F. crispus.*
——— *Forbesi.*
Nassa pliocena.
Nassa monensis.
Natica (Bulbus) Smithii.
Mitra ?

6. Of species, fossil in the coralline or red crag, but still existing in the South-European though not in the British Seas.

Turritella incrassata.

7. Of extinct species, fossil also in the crag.

Tornatella pyramidata.

This fauna, then, is composed of living British species of northern origin, some of which are now confined to climates far colder than our own, with a few forms supposed to be extinct, and one or two shells of southern origin, or known only in the crag. It is important to observe that the latter are from the southernmost parts of these deposits in Ireland, where are also found members of the crag monstrosity of *Fusus antiquus,* known as *Fusus contrarius*, and the variety of *Purpura lapillus,*

formerly termed *Purpura incrassata*. It is also of consequence to note the fact that the species most abundant, and generally diffused in the drift are essentially northern forms such as *Astarte elliptica, compressa,* and *borealis, Cyprina communis, Leda rostrata* and *minuta, Tellina calcarea, Modiola vulgaris, Fusus bamfius* and *scalariformis, Littorinæ* and *Lacunæ, Natica clausa* and *Buccinum undatum*; and even *Saxicava rugosa* and *Turritella terebra*, though widely distributed, are much more characteristic of north European than of southern seas.

I have elsewhere shown* that among marine animals, zones of depth correspond to parallels of latitude, even as the latter are, in like manner, represented on land by zones of elevation. When I made known the facts proving this law, I did not distinguish between the law as really maintained by representative forms, and as apparently exemplified by identical species. This distinction I have pointed out in this essay when treating of alpine plants. It will be seen by and by that it is equally important to bear it in mind, in the case of the boreal forms of marine animals found at great depths in southern seas. The truth of the law itself, however, holds good, and the knowledge of its existence naturally leads us to inquire how far the apparently boreal or arctic fauna of the glacial beds might owe their climatal character to such a cause. This is an important question, for unless we can determine positively that *depth* was not the element to which the peculiar *facies* and numerical weakness of this submarine fauna were due, our climatal determinations, so far as they depend on zoological data, become mere hypotheses.

Fortunately, however, among the species enumerated are several which ought to afford us a certain clue to this matter. Such are the *Littorinæ*, the *Purpura*, the *Patella*, and the *Lacunæ*, genera and species *definitely* indicating, not merely shallow water, but in the three first cases a coast line. Were these shells only found among the disturbed and amorphous beds of drift, they would scarcely serve as evidence on so nice a point, since they might have been transported; but they occur also in the undisturbed fossiliferous clays of this formation, associated with bivalve and other mollusca of delicate conformation and in a state which certainly indicates that they lived and died on the spots where they now are found. This is especially the case among the Clyde deposits. A most important fact, too, is that among the species of *Littorina*, a genus, all the forms of which live only at *water-mark*, or between *tides*, is the *Littorina expansa*, one of the forms now extinct in the British, but still surviving in the Arctic Seas.

To make this evidence more clear, it is necessary briefly to notice the *vertical* distribution, or distribution *in depth* of existing mollusca in the British Seas.

* Report on the Mollusca and Radiata of the Ægean Sea, in Reports of the British Association for 1843.

In an essay 'On the Associations of Mollusca on the British Coasts, considered with reference to Pleistocene Geology,'* printed in 1840, I described the mollusca as distributed on our shores and seas in four great zones or regions, severally denominated "the Littoral zone," "the region of Laminariæ," "the region of corallines," and "the region of corals." An extensive series of researches, chiefly conducted by the members of the committee appointed by the British Association to investigate the marine zoology of Britain by means of the dredge have not invalidated this classification, and the researches of Professor Löven in the Norwegian and Lapland Seas have borne out their correctness. The first two of the regions above mentioned had been previously noticed by Lamouroux, in his account of the distribution (vertically) of seaweeds; by Audouin and Milne Edwards, in their 'Observations on the Natural History of the Coast of France,' and by Sars in the preface to his 'Bagtivelser og Jagtivelser.' The Littoral distribution of mollusks has frequently attracted the attention of zoologists. An admirable essay on the fauna and flora of the Littoral and Laminarian zones on the coast of Denmark has recently been published by M. Oersted.

The first, or *Littoral zone*, is that tract which lies between the high and low water marks, and therefore is very variable in extent, depending for its dimensions on the amount of rise and fall of the tides. In all parts of the northern hemisphere it presents very similar phenomena when its animal and vegetable inhabitants are examined, whether it be only a few inches broad, as in the Mediterranean, or beyond 30 feet in vertical extent, as in some more tidal seas. Throughout Europe, wherever it consists of *rock*, it is characterized zoologically by species of *Littorina*, botanically by *Corallina*; where *sandy*, by the presence of certain species of *Cardium*, *Tellina* and *Solen*; where *gravelly*, by *Mytilus*; where *muddy*, by *Lutraria* and *Pullastra*.

In the British Seas its inhabitants vary in the northern and southern districts, but there are many species constant throughout, both of plants (as the species of the genera *Fucus*, *Lichina*, *Laurencia* and *Corallina*), and animals (as *Littorina rudis*, *littorea* and *neritoides*, *Purpura lapillus*, *Patella vulgata*, *Cardium edule*, *Kellia rubra*, and many Annellides and Zoophytes, never found out of this region). This zone is itself divisible into several distinct sub-regions as well defined by characteristic animals and plants where it is narrowest as where it is broadest. To show that this assertion of the constancy of even the sub-divisions of the littoral zone is not put forth vaguely, but from minute observation (which is equally true in regard to the statements respecting the other zones in depth), I append a table† exhibiting the characteristic animals and plants

* Edinburgh Academic Annual for 1840. † See p. 373.

of the several littoral sub-regions, as noted by myself at six British localities, three northern and three southern, each presenting a different condition of sea-bottom, and considerable variation in amount of rise and fall of tides. In the first column I give the distribution as observed at Sandwick, on the east coast of the mainland of Zetland, where the fall of the tide is very small, and the shore composed of steep rocks of gneiss. Extremely unfavourable as such a locality must be to animal and vegetable life, we see, nevertheless, that such species as do occur take their respective places with as much deference to right of precedence as in the more favoured localities with which it is compared. The second and third exhibited the littoral distribution as observed at Armadale, in the sound of Skye, at one point on rock (old red sandstone), at another in a shingly bay. The presence of *Lottia testudinaria* in this column is a feature indicative of the *Boreal* type of the fauna. The fourth column exhibits the distribution as noted on limestone at Slade, on the sea-side of Hook-point, the southern extremity of the county of Wexford; and the fifth, on the old red sandstone coast in the same district. In both these we see evidences of a more southern fauna in the presence of *Trochus crassus*, a characteristic species of the *South British* type of our native mollusca, whilst the occurrence of *Trochus umbilicatus* here, as well as in the Armadale column, is characteristic of the western seas of Britain generally. In the Zetland and Armadale columns the *Spirorbis* marks a zone much more distinctly than in those of the southern localities. The sixth column is an incomplete (in consequence of the time of tide) note of the distribution on a Silurian rocky shore at Tramore, in the county of Waterford. In all these columns the several members of each sub-region are to be understood as intermingled, except when it is expressly stated to the contrary; and several of the members of the third and fourth sub-regions occasionally stray into the first and second. The abundance of animal life in the littoral zone and its respective sub-divisions must not be judged of from the number of species named in this table—my object at present being not to give lists of their flora and fauna, but to show how well marked, by characteristic forms, such zones are.

The importance of a knowledge of the characteristic features of the littoral zone, to the geologists investigating the northern drift, cannot be too strongly enforced, seeing that the evidences of them presented by fossils are the surest tests of ancient coast lines, and guides to the determination of the amount of elevation, or depression, and direction of action of the disturbing force.

The second, or *Laminarian* zone, is that land-encircling belt which commences at low water mark, and extends to a depth of from seven to fifteen fathoms. The great tangle seaweeds form miniature forests in

Divisions of LITTORAL ZONE.	SANDWICK, E. of ZETLAND, on steep rocks of gneiss. Vertical extent four feet.	Near ARMADALE, W. coast of SKYE. Shingle and Sand.	Near ARMADALE, W. coast of SKYE. Old Red Sandstone Rocks.	At SLADE, County WEXFORD. Carboniferous Limestone Rocks.	At FEATHERD. County WEXFORD. On Old Red Sandstone Rocks.	At TRAMORE, County WATERFORD. On Silurian slates.
I. SUB-REGIO.	*Fucus canaliculatus.* Littorina rudis.	*Fucus canaliculatus.* Littorina rudis.	*Fucus canaliculatus.* Littorina rudis. A few Balani.	*Fucus canaliculatus.* Littorina rudis, and petræa.	*Fucus canaliculatus.* Littorina rudis. A few Balani and Patellæ.	*Fucus canaliculatus.* Littorina rudis, petræa, and Balani.
II. SUB-REGIO.		*Lichina.* Patella vulgata. Balanus.	*Lichina.* Patella vulgata. Mytilus edulis.	*Lichina.* Patella vulgata. Balanus. *Nullipora.*	*Lichina.* Patella vulgata. Balanus. Mytilus edulis. *Nullipora.*	*Lichina.* Patella vulgata. Balanus. Mytilus edulis.
III. SUB-REGIO.	{ *Fucus articulatus.* { Balanus. { Littorina littorea. { Purpura lapillus. { *Fucus nodosus.*	*Fucus articulatus.* Balanus. Littorina littorea. Purpura lapillus. Actinea mesembryanthemum. *Fucus nodosus*, forming a distinct belt.	*Fucus articulatus* and *Fucus nodosus*, mingled. Patella vulgata and Balani, abundant. Littorina littorea. Purpura lapillus, abundant. Trochus umbilicatus. Spirorbis on rocks. *Corallina officinalis.*	*Fucus articulatus* and *nodosus*, mingled. Balanus. Littorina littorea. Purpura lapillus. Trochus crassus. Actinea mesembryanthemum.	*Fucus articulatus.* Balani, abundant. Littorina littorea. Purpura lapillus. Trochus umbilicatus, and crassus. Actinea mesembryanthemum.	*Fucus articulatus.* Balani and Patellæ. Littorina littorea. Purpura lapillus. Trochus umbilicatus. Actinea mesembryanthemum. *Corallina officinalis.*
IV. SUB-REGIO.	*Fucus serratus*, its fronds covered with spirorbis.	*Fucus serratus*, its fronds covered with spirorbis. Littorina neritoides. Lottia testudinaria.	*Fucus serratus*, mingled with *nodosus.* Spirorbis. Littorina neritoides. Trochus cinerarius. A few Balani.	*Fucus serratus.* Littorina neritoides. Trochus cinerarius and umbilicatus, with occasional specimens of T. ziziphinus.	*Fucus serratus.* Littorina neritoides. Trochus cinerarius. A few Patellæ and Balani.	*Fucus serratus.* Littorina neritoides.
Intermediate bands, only a few inches broad, everywhere.	*Himanthalia.*	*Conferva rupestris*, forming a belt.	Four belts of Fuci. 1. *Laurencia pinnatifida.* 2. *Conferva rupestris.* 3. *Chondrus crispus.* 4. *Himanthalia lorea.*	*Chondrus crispus*, and *Himanthalia lorea.*	*Himanthalia.*	*Himanthalia.*
REGION OF LAMINARIÆ.	*Laminariæ.*	Sand with *Zostera.*	*Laminaria.*	*Laminaria*, and *Delesseria.*	*Laminaria.*	*Laminaria.*

this region, associated with such fuci as algologists usually deem inhabitants of deep water. A host of animals reside upon these algæ. Among mollusca, the genera *Lacuna* and *Rissoa*, the *Patella pellucida* and *lævis*, *Pullastra perforans* and *vulgaris*, and various *Modiolæ* are especially characteristic of this zone; and numerous zoophytes and *Radiata* especially *Echinus sphæra*, *Tubularia*, *Actinea senilis*, though ranging both higher and lower, are more prolific here than in any of the other regions. The coral-like *Nullipora* is the last and bounding plant of this zone in our seas, and rarely ranges with us below 20 fathoms at the utmost; though in more southern seas, as in the Mediterranean, it is found abundantly at depths as great as 70 and 80 fathoms, where, as here, it forms the out-post of marine vegetation in depth.*

The third province in depth I have termed the *Region of Corallines*, for in it we find the greatest variety and abundance of the corneous zoophytes—arborescent animals, which seem here to take the place of plants. Here we find the great assemblage of carnivorous mollusca, the species of *Fusus*, *Pleurotoma*, and *Buccinum*, and many of the species of *Trochus*. Here too are most abundant the *Naticæ*, *Fissurellæ*, *Emarginulæ*, *Velutinæ*, *Capulus*, *Eulimæ*, and *Chemnitziæ*, and among bivalves, *Artemis*, *Venus*, *Astarte*, *Pecten*, *Lima*, *Arca*, and *Nucula*. Numerous and peculiar *Radiata*, including the largest and most remarkable species, abound, and, for number, variety, and interest of the forms of animal life in the British Seas, this region transcends all the others. Its vertical range is from 15 to about 50 fathoms; its chief development between 25 and 35 fathoms.

The fourth and lowest of the regions of depth in the British Seas, I have termed the region of *deep-sea corals*. It is necessarily local as the greater extent of our marine area does not attain the depth at which this region commences, zoologically about 50 fathoms, or possibly considerably deeper. It has as yet been but very partially explored, but so far we know, is well characterized by the abundance of the stronger corals, the presence in quantity of species of the *Dentalium*-like genus of *Annelides*, called *Ditrupa*, by a few peculiar *Mollusca*, and by peculiar *Echinodermata*, as *Astrophyton* and *Cidaris*, and *Amorphozoa*, as *Tethya cranium*. All our British *Brachiopoda* inhabit this zone, and probably

* In one of the latest published summaries of the state of our knowledge of botanical geography (Endlicher and Unger's 'Grundzüge'), 200 feet is given as the probable lowest limit of the distribution of algæ in depth; and in most botanical manuals, Humboldt's observation of the occurrence of *Fucus vitifolius*, at a depth of 192 feet in the seas of the Canaries is quoted as the extreme instance. The following instances of equal and greater ranges of algæ observed by myself in the eastern Mediterranean, show how much deeper marine vegetation extends there than in more northern seas:—*Codium flabelliforme*, 30 fathoms; *Microdictyon umbilicatum*, 30 fathoms; *Rityphlæa tinctoria*, 50 fathoms; *Chrysymenia uvaria*, 50 fathoms; *Dictyomenia volubilis*, 50 fathoms; *Constantinea reniformis*, 50 fathoms; *Nullipora polymorpha*, 95 fathoms.

range throughout it. Even, in certain localities, where they are found in shallower water inhabiting the region of corallines, there are reasons, as will afterwards be shown, for believing that such cases are apparent anomalies which may be explained by reference to geological changes.

The following table may be useful as exhibiting at a glance the characteristic features of the several zones of depth in the British Seas.

Table of the Regions of Depth of the British Seas.

	Characteristic Plants.	Characteristic Animals.
I. LITTORAL ZONE. The tract betweeen tide marks.	First Subregion. *Fucus canaliculatus.* Second Subregion. *Lichina.* Third Subregion. *Fucus articulatus.* Fourth Subregion. *Fucus serratus.*	*Patella vulgata* throughout. First Subregion. *Littorina rudis.* Second Subregion. *Mytilus edulis.* Third Subregion. *Littorina littorea.* *Purpura lapillus.* Fourth Subregion. *Littorina neritoides.* *Trochi.*
	Himanthalia lorea.	
II. LAMINARIAN ZONE. Tract between low-water mark and 15 fathoms.	Subregio superior. *Laminariæ.* *Rhodomeniæ.* *Delesseriæ.* Subregio inferior. *Nullipora.*	*Trochus Ziziphinus.* *Lacunæ.* *Patella pellucida.* *Patella cærulea.* *Rissoæ.*
III. REGION OF CORALLINES. 15 to 50 fathoms.	?	*Hydroid zoophytes* throughout. Subregio superior. *Fusus antiquus.* *Pullastra virginea.* *Pecten maximus.* Subregio inferior. *Pleurotoma teres.* *Turbinolia milletiana.*
IV. REGION OF DEEP SEA CORALS. 50 fathoms to beyond 100.	0	Subregio superior. *Neæræ.* *Celleporæ.* *Brachiopoda.* *Ditrupa.* Subregio inferior. *Astrophyton.* *Cidaris.* *Oculina.* *Primnoa.*

I have already mentioned that in the glacial deposits the existence of the first of these regions in depth—the *littoral zone*—is well marked by the surest evidence—the presence of species of *Littorina* in situ. Having thus got a definite point of the greatest possible amount of shallowness, let us see what evidence those deposits offer of depth. That in no case, so far as I have examined, the upheaved strata were formed under conditions of considerable depth, such as my *region of deep-sea corals* now presents, is rendered almost certain by the total absence of the remains of the characteristic inhabitants of that region. This could not have been owing to the decay of such remains, for the persistency of the characteristic deep-sea corals of our own and the Arctic Seas, is, from their compactness and size, greater than that of any of the mollusks which have been preserved. We find no traces in these deposits, for instance, of the great *Oculina prolifera*, still living in the depths of the Zetland Seas and off the coast of Norway; nor of the characteristic *Turbinolia, Caryophylleæ, Celleporæ*, and smaller corals; nor of the great northern Asteroids, such as *Primnoa lepadifera* and *Alcyonium arboreum*, which, from their gigantic size, being equal in dimensions to small trees, would certainly have left some evidence of their existence behind. Instead of these, we get an association of species, which, if we proceed sufficiently far north, we may still find living in the shallows of colder seas, and the greater number of them within the range of the three first regions of our own.

We have a right, then, to infer that the associations of testacea observed in the British glacial deposits, present a northern or arctic aspect as compared with our existing marine fauna, not owing to conditions of greater depth prevailing during the epoch of their existence, but owing to a general colder climate affecting the area within which they are found, and due to causes not now in operation within that area. As these beds in Britain probably approached the southernmost bounds in Europe of the true glacial formation, the regions more to the north in which similar beds are found with similar fossils, must have been formed under similar, and, judging from the greater paucity of species of organic remains in them as compared with the numbers in the British beds, probably severer climatal conditions. So far as I have seen, there is no British case of an upheaved stratum of the glacial formation containing organic remains evidently untransported, which may not have been formed at a less depth than 25 fathoms, and as the *Nullipora* occasionally occurs in the deeper beds—to which belong most of the clays and marls—it is probable that between 10 and 15 fathoms would more frequently approach the truth. Over a great part of the areas occupied by these glacial beds, we find the uppermost portion composed of sand and gravel, containing fossils more

general, littoral, and indicating a much less depth of water than existed previously during the deposition of the marls. The abundance of *Purpura lapillus*, and the presence of *Littorina littorea*, may be mentioned as especially characteristic of the shelly gravels which in Wexford have been found by Captain James to contain numerous specimens of the reversed variety of the *Fusus antiquus*, known under the name of *Fusus contrarius*, and common in the red crag. At present the reversed form is as rare among specimens of that Fusus, as the dextral form was anciently. It is difficult to conjecture a sufficient cause for the prevalence of the monstrous over the normal form during two geological epochs. The discovery by Captain James of *Turritella incrassata* (a crag fossil), of a southern form of *Fusus*, and of a *Mitra*, allied to a Spanish species, in these southern Irish beds, associated with the usual glacial species, is an important fact, suggesting the probability of a communication southwards of the glacial sea with a sea inhabited by a fauna more southern in character than that now existing in the neighbourhood of the region where these relics were found. It is a fact which will bear strongly on the question of the point of time, whether before, during, or after the *glacial epoch*, certain freshwater beds containing important fossils, remains of vertebrata and mollusca, were deposited. It also bears importantly on the general question of the distribution of climates on this side of the Atlantic during the later tertiary periods. At present we have an intermediate (the *Celtic*) marine fauna, separating the *Boreal* and *South-European* or *Lusitanian* types. But that such an intermediate type need not have existed at a time when the Boreal fauna ranged, almost exclusively, farther south than now, we may convince ourselves by looking to the state of the marine fauna at the opposite coasts of the Atlantic. In latitude 42° N., we find a cape of no great prominence, and of recent geological origin, constituting the barrier, or rather marking the line of demarcation between a fauna of character in great part as northern as that which prevailed in our seas during the glacial period, and one of fully as southern a character (if not more so) as that now prevailing on the coasts of Portugal. For a short space, and but a very short space, the two faunas intermingle; but there is no distinct intermediate marine fauna like that now widely separating the northern and southern European types. The best evidence I can quote on this subject is that of Dr. Gould, whose State Report on the Invertebrata of Massachusetts, is a most carefully elaborated and excellent work. In summing up his results, he notices the collision of the two types of marine fauna alluded to as follows: "Cape Cod, the right arm of the commonwealth, reaches out into the ocean some fifty or sixty miles. It is nowhere many miles wide; but this narrow point of land has hitherto

proved the barrier to the migrations of many species of Mollusca. Several genera and numerous species, which are separated by the intervention of only a few miles of land are effectually prevented from intermingling by the cape, and do not pass from one side to the other. No specimen of *Cochlodesma, Montacuta, Cumingia, Corbula, Janthina, Tornatella, Vermetus, Columbella, Cerithium, Pyrula*, or *Ranella*, has yet been found to the north of Cape Cod; while *Panopæa, Glycimeris, Terebratula, Cemoria, Trichotropis, Rostellaria, Cancellaria*, and probably *Cyprina* and *Cardita*, do not seem to have passed to the south of it. Of the 197 marine species (of the Massachusetts fauna), 83 do not pass to the south shore, and 50 are not found on the north shore of the cape. The remaining 64 take a wider range, and are found on both sides." (p. 315). A little farther north and we have the contrast still more evident on each side of Cape Breton, the true boundary southward on the coast line of the *Boreal* fauna, which north of it ranges on to Greenland, and is probably very nearly the existing representative of the ancient fauna of our seas during the glacial epoch.

The probability of the peculiar fossils noticed as occurring only in the southernmost Irish beds of the glacial epoch, indicating a proximity of the glacial sea with one peopled by mollusks of a Lusitanian type, is supported by the fact that in the newer pliocene beds of southern Italy, we find associated with the characteristic existing mollusca of the Mediterranean certain Red Sea and Indian Ocean species on the one hand, and Celtic species on the other, both now extinct in that region. It is worthy of notice, that the Celtic fossil species found in the Sicilian beds, *Mya truncata, Lutraria solenoides, Cyprina islandica, Ostrea edulis, Patella vulgata, Fusus antiquus contrarius*, and *Buccinum undatum*, present the association of species characteristic of the southern bounds of glacial beds in Britain; and it can scarcely be doubted that during the newer pliocene epoch, which I regard as synchronic with the *glacial* period in the north, there was a communication open between the Mediterranean and North Seas on the one hand, by which this influx of *Boreal* or *Celtic* forms was acquired, whilst, on the other, there was, or had lately been, a free communication with the Indian Ocean through the Red Sea,—the Isthmus of Suez not existing.*

* See the valuable *Enumeratio Molluscorum Siciliæ* of Dr. Phillippi, especially the Second Part and its Appendix. Also the papers of that most judicious naturalist, translated in the first volume of the Journal of the Geological Society. See also my 'Report on the Mollusca and Radiata of the Ægean Sea,' in the volume of the British Association Reports for 1843. I may here mention, that the boreal Mollusca above named as present in the newer pliocene of Sicily, are *not* present in the newer pliocene of Rhodes, whilst I have reason to believe that the Red Sea forms are more abundant in the Rhodian tertiaries, than in those of Southern Italy. These facts may afford a clue to the probable course of migration of the northern and southern extinct forms found in the Mediterranean newer pliocene.

The northern and western relations of the glacial testacea are very remarkable. Not only are several of the characteristic species, as we have already seen, identical with forms now known only in Arctic Seas, or on the coasts of Boreal America, but fully a third of the entire assemblage are species still existing in the American Seas, and at the same time on the coasts of Europe. At the present day there are sixty-six species of testaceous mollusks common to the coasts of the United States, north of Cape Cod, and Europe. Of these sixty-six species, not one has its northern European limit south of Britain, and only ten (excluding two pelagic forms) range to the seas of Southern Europe, and of these some are doubtful identifications. On the other hand, no fewer than forty-five are recorded inhabitants of the Arctic Seas,—and probably many more live there, for I have no lists by which to institute a comparison of the British fauna with that of Lapland, or even Iceland. In the following table the first column contains the names of testacea common to Europe and North America, as recorded by American authors of repute, especially Dr. Gould, who took every pains to identify his species correctly with their European analogues. Some few of these are doubtful; and it will be observed, that the doubtful species are just those deficient in the middle column, exhibiting the localities in which the species have been found fossil in beds of the glacial epoch. In the third column the European and Arctic ranges of the species are given. This table shows that no fewer than fifty-one out of the sixty-five are known as glacial fossils. Of the remaining fourteen, two, viz., *Spirula Peronii* and *Janthina fragilis* are pelagic mollusks wandering from the south, and with them may be classed *Teredo navalis*, carried about in floating wood. Two, *Kellia rubra* and the *Skenea*, are minute species living in stony ground near highwater-mark, and not likely to be preserved fossils; whilst the three *Chitons*, although larger from inhabiting similar situations, and being extremely fragile, falling to pieces after death, are in the same category. The *Modiola glandula* (*Crenella decussata* of English conchologists) is also a minute shell. *Modiola discrepans* and *discors* are doubtful identifications. The remainder, including *Buccinum Donovani*, and two species of *Margarita*, may yet be expected to occur in the drift.

From this table we may fairly infer, that the identity, so far as it exists, between the testaceous fauna of Boreal America and that of Europe, was established, at latest, during the glacial epoch; and the occurrence of some American forms in the crag, as we have previously mentioned, would show that it commenced prior to that epoch. It is very important to observe that the ancient relationship between the marine mollusks of the new and old world is not maintained by pelagic species or floaters—the few of those in the list are recent introductions

Mollusca common to the East coasts of North America and Europe (as named by American authors).	Places where the same species are found fossil in formations of the Glacial Epoch.	Distribution of the species in the Arctic and European Seas.
Teredo navalis	. . . .	General, from Greenland southwards.
Pholas crispatus . . .	Sweden, Britain . . .	Seas of Northern and Western Europe.
Solen ensis	Ireland	Scandinavian, Celtic, and South European Seas.
Panopæa arctica . . .	Clyde	Northern Seas, very rare near Britain.
Mya arenaria	Britain.	Greenland, Scandinavian, and Celtic Seas.
Mya truncata and var. β .	Britain, Sweden, Russia, Canada.	Greenland, Scandinavian, and Celtic Seas. (The variety β not now known alive in Europe).
Mesodesma Jauresii (Mactra deaurata).	. . . .	A doubtful or very rare European species.
Tellina groenlandica . .	Russia, Canada . . .	Arctic Seas (Icy Cape).
Kellia rubra	. . . .	Greenland? Northern, Celtic and Mediterranean Seas. Ranges farther south. Lives at water-mark.
Saxicava rugosa . . .	British, Swedish, Russian beds.	Greenland, and all the European Seas, and as far south as the Canaries.
Lucina radula	Scotland? Sweden? . .	Celtic and Mediterranean Seas.
Lucina flexuosa . . .	Scotland	Greenland; Northern, British, and Mediterranean Seas.
Astarte compressa . . .	Britain.	Greenland, Scandinavian, and British Seas.
Astarte danmoniensis (with scotica).	Britain, Sweden, Russia .	British and Northern Seas.
Astarte borealis . . .	Britain, Sweden, Russia .	Arctic, Norwegian, and Zetland Seas.
Cardium groenlandicum .	Russia	Arctic Seas.
Cyprina islandica . . .	Britain, Denmark . .	Northern and British Seas.
Nucula (Leda) hyperborea (var. of myalis?)	Ireland, Sweden, Canada	Arctic Seas.
Nucula (Leda) minuta .	Britain, Russia? . . .	Greenland, Scandinavian, and British Seas.
Nucula tenuis	Scotland	Greenland; North British Seas.
Mytilus edulis	Britain, Sweden, Russia, Canada.	Greenland, Northern and Celtic Seas.
Modiola vulgaris . . .	Britain, Sweden . . .	Scandinavian and Celtic Seas.
"Modiola discrepans" (nigra?).	. . . .	(If identical), Greenland, Scandinavian, and North British Seas.
"Modiola discors" (our discrepans?)	. . . .	(If identical), Greenland, Northern, Celtic, and South European Seas.
Modiola glandula (Crenella decussata).	. . . .	Greenland. North British Seas.
Pecten islandicus . . .	Scotland, Sweden, Russia, Canada.	Greenland, Iceland.
Ostrea borealis (a var. of edulis?)	(*edulis*) in Scottish beds.	(*edulis*), Northern, Celtic, and south European Seas.
Anomia ephippium . .	Scotland, Sweden . .	Northern, Celtic, and South European Seas.
Anomia aculeata . . .	Ireland	Same as the last.
Terebratula caput serpentis.	Sweden	Northern, Celtic, and Mediterranean Seas.
Terebratula psittacea .	Britain, Canada . . .	Greenland, Scandinavian, and north British Seas (Laskey MSS.).
Chiton marginatus. . .	. . . .	Scandinavian and British Seas.

Mollusca common to the East coasts of North America and Europe (as named by American authors).	Places where the same species are found fossil in formations of the Glacial Epoch.	Distribution of the species in the Arctic and European Seas.
Chiton ruber (?) . . .	. . . .	Greenland, Scandinavian, and British Seas.
Chiton albus (?) . . .	. . . .	
Lottia testudinalis . .	Sweden	Greenland, Scandinavian, and North British Seas.
Cemoria noachina . . .	Scotland, Sweden . .	Greenland, Scandinavian, and Seas north and west of Scotland.
Natica clausa	Scotland, Sweden, Russian, Canadian.	Arctic Seas.
Janthina fragilis . . .	. . . .	Oceanic (Mid-Atlantic).
Velutina lævigata . . .	Scotland	Greenland, Scandinavian, and British Seas.
Velutina zonata (V. undata, Brown).	Clyde	Arctic Seas.
Sigaretus haliotoideus (=S. perspicuus).	Sweden	British, Mediterranean, and Lusitanian Seas.
"Skenea serpuloides," (from the description and figure this should be *Skenea depressa*, and not *serpuloides* of Montagu, to which it is referred by Dr. Gould).	. . . .	Greenland, Scandinavian, and British Seas.
Scalaria groenlandica . .	Sweden	Greenland.
Margarita cinerea (Tr. inflatus? Smith.)	Scotland, Sweden . .	Arctic and Norwegian Seas.
Margarita undulata . .	. . . .	Greenland (Zetland, var. β?).
Margarita arctica (M. vulgaris).	. . . .	(*M. vulgaris*). Greenland, Scandinavian, and north of Britain.
Littorina rudis and var. tenebrosa.	Britain, Sweden . . .	Greenland, Iceland, Norwegian, and British Seas.
Littorina palliata (L. expansa, Brown).	Scotland	Greenland and Norway.
Lacuna vincta	Scotland	Scandinavian and British Seas.
Lacuna neritoides (L. Montagui?)	Ireland	Norwegian and British Seas.
Pleurotoma decussata (P. reticulata, Brown).	Scotland	Scottish Seas.
Fusus islandicus (F. corneus of British authors).	Britain, Sweden . . .	Greenland, Scandinavian, and British Seas.
Fusus Sabini	Ireland	Arctic Seas, Zetland.
Fusus tornatus (carinatus, Laskey).	Scotland, Canada, Russia	Greenland, Finmark, and British Seas (very rare).
Fusus scalariformis . .	Britain, Sweden . . .	Arctic Seas.
Fusus Bamffius . . .	Britain.	Greenland, Scandinavian, and British Seas.
Fusus rufus?	. . . .	British Seas.
Fusus turricula . . .	Britain	Greenland, Scandinavian, and Celtic Seas.
Fusus muricatus? . . .	Ireland	Celtic and Mediterranean Seas.
Trichotropis borealis . .	Canada	Greenland, Norwegian, and Scottish Seas.
Purpura lapillus . . .	Britain	Greenland, Scandinavian, and Celtic Seas.
Buccinum Donovani (B. glaciale of British authors).	. . . .	Greenland. Zetland?
Buccinum undatum . .	Britain, Sweden, Russia .	Greenland, Scandinavian, and Celtic Seas.
Buccinum ciliatum (B. Humphreysianum).	Scotland? Canadian .	Greenland, Scandinavian, and Celtic Seas.
Spirula Peronii . . .	. . . .	Oceanic (Mid-Atlantic).

—but by *ground-feeders* and *littoral forms*. Sir John Richardson, in his admirable 'Report on the Zoology of North America,'* observed a similar peculiarity in the distribution of the vertebrate animals common to North America and Europe. Writing of the fishes of the order *Malacopterygii sub-Brachiales*, he remarks, "Most of the fish of this order feed on or near the bottom, and a very considerable number of the species are common to both sides of the Atlantic, particularly in the higher latitudes, where they abound. It does not appear that their general diffusion ought to be attributed to migration from their native haunts, but rather that in this respect they are analogous to the owls, which, though mostly stationary birds, yet include a greater proportion of species common to the old and new worlds than even the most migratory families. Several of the *Scomberoideæ*, which feed on the surface, have been previously noted as traversing many degrees of longitude in the Atlantic; but the existence of the ground-feeding *Gadoideæ*, in very distant localities, must be attributed to a different cause, as it is not probable that any of them wander out of soundings or ever approach the mid-seas" (p. 218). This is as true of the mollusks as of the fish, and, doubtless, the cause is one and the same in each case. That cause must be sought for in the conditions presented by the North Atlantic and Arctic Seas during the glacial epoch. Since that period there appears to have been no interchange of species between the Northern Seas of the old and new world, so far as mollusks are concerned. New forms have arisen among the old ones, created to derive the benefits of new conditions; strangers have migrated along the coasts from the south on both sides of the Atlantic—their fry, during their natatory condition, availing themselves of the transporting powers of favouring currents; old species have returned to colder climes and limited their range, or in some cases have altogether disappeared; but not a single littoral or coast-inhabiting mollusk has found its way across the Atlantic in either direction since that ancient time, anterior to all human records, and probably long anterior to the appearance of man on our earth, when an Arctic Sea, inhabited by a limited and uniform fauna, extended from the then western coasts of Siberia into the heart of North America, and southwards in Europe to the parallel of the Severn, and in America to near that of the Ohio. This uniformity of fauna,† this diffusion of littoral and nonmigratory forms, must have owed its existence to uniformity of conditions not now met with within that area. There could not then have been such a separating abyss between Northern Europe and Boreal America as now divides them; the sea, through a great part,

* Reports of the British Association for the Meeting at Bristol.

† Mr. Lyell first called attention to this important fact of the correspondence of the European and American fauna during the glacial period.

must have been a shallow sea, and somewhere, probably far to the north, there must have been either a connexion or such a proximity of land as would account for the transmission of a non-migratory terrestrial, and a littoral marine fauna. Such are the indications afforded by zoological evidences: they are, doubtless, closely connected with the history of the climatal changes which terminated the epoch we are considering.

It has been already stated that the remains of testacea through a great part of the glacial or drift-beds, are in a fragmentary or rolled state, and are not distributed in *horizons* (as they would be if the ground on which they lived had been elevated undisturbed), but are often scattered through confused and unstratified masses of mud and sand or gravel. It has also been stated that this is not everywhere the case: that in certain localities we find the organic remains forming well defined horizons, and in such a state of preservation as to indicate that they lived and died on the spots where they are found; and that among these undisturbed localities we find some which, containing littoral fossils *in situ*, indicate the lines of coast and tide-mark. These facts suggest two questions: 1st, what were the disturbing influences? and, 2nd, how far are we to regard all drift beds containing marine remains as having been formed beneath the sea, on the spots where they now are found?

So far as I have observed the fossils in the great exposed tracts of northern drift, as in Ireland, the north of England, and the Isle of Man, are generally fragmentary or rolled. Occasionally strata occur in the midst of the beds less disturbed than the greater part of them, and containing shells apparently *in situ*; but through the greater part of the epoch of their deposition, disturbing influences appear to have been at work throughout the area of the glacial sea. These disturbing influences were probably of two kinds—the *ploughing-up* action of icebergs, and the *sweeping* action of great waves coming from the north.

To the first may be attributed the general confused condition of the mud bottoms, and the fragmentary and disturbed state of their included fossils, which are all species, *not transported*, but occurring in undisturbed localities, in such a state as to prove that they were indigenous to the seas in the upheaved beds of which they are now found.

To the second, the transport to very high levels of masses of marine drift with organic remains, may be referred, either by washing up, high and dry, portions of the sea-bed, or by propelling and stranding masses of ice which, in their turn propelled before them the contents mineral and organic of the sea. For the evidence presented by glacial testacea *in situ* in all tracts of sufficient extent within the area of the British Isles, shows that at no period during their existence was there a very

deep sea through the upheaved parts of that area, but on the contrary, that very generally it was a shallow sea which then prevailed, one, judging, from the organic remains, not probably beyond 15 fathoms or so deep. This the occurrence of *Nullipora* in the parts presenting greatest appearances of depth shows, and beds containing deep-sea Arctic species are nowhere exposed. Besides which we have, as has been already shown, distinct evidence of the coast lines of that epoch. Yet fossils, and those too, not littoral species, occur at very high levels, as for instance in Mr. Trimmer's famous case of Moel Trefaen, in North Wales, where beds of gravel and sand containing glacial marine testacea occur at a height of 1,500 feet above the present sea level. These fossils are deposited in the museum of the Geological Society, where I have lately examined them carefully with a view to see whether they indicate an ancient coast line and beach, or an ancient sea-bottom. But they cannot be regarded as indicating either, being a confused mixture of fragments of species from all depths, both littoral and such as invariably live at a depth of many fathoms—of such species as *Astarte elliptica*, *Mytilus edulis*, *Tellina solidula*, *Cardium edule*, *Venus gallina*, *Buccinum undatum*, *Mactra solida*, *Dentalium entalis*, *Cyprina islandica* and *Turritella terebra*, inhabitants, some of muddy grounds, some of sandy, some of rocky. Deep and shallow water species mingled could at no time have lived together, or have been thrown up on one shore. They indicate the action of some disturbing influence—of having been accumulated far above the level of the then existing sea, through the agency of an iceberg, as suggested by Mr. Darwin, or through the agency of a wave of translation, such as Sir Roderick Murchison has shown to play so important a part in producing the phenomena of the Scandinavian and Russian drifts; or possibly by the combined action of both causes. That such propelling forces derived from afar, were powerful agents of disturbance at the period under consideration, is also rendered probable by the fact that the chief localities of stratified glacial beds, containing undisturbed testacea evidently *in situ*—as, for instance, great beds of *Pecten islandicus*, *Panopæa arctica*, and even such delicate forms as *Nuculæ*, *Tellinæ*, and *Lucinæ* in the position in which they lived, and with both valves connected, are to be found in the Clyde districts (where this fact was noted by Mr. Smith) in localities sheltered to the north by mountain ridges which were anciently islands in the glacial sea. These islands had saved many tracts of sea from the disturbing influences of icebergs, and great advancing waves, the course of which, from the north, is indicated by the protected beds; for it is worthy of note that the glacial beds in the northern districts of Scotland, which had no such protecting barriers to defend them—as, for instance, those at Wick—present the same disturbed and unstratified

conditions, and similar rolled and broken fossils with those so characteristic of most of the glacial beds around the Irish Sea.

The upheaval of the bed of the glacial sea, was not sudden but gradual. The phenomenon, so well described by Professor Forchhammer in his essays on the Danish drift, indicating a conversion of a muddy sea of some depth, into one choked up with sand banks, though not universal, are equally evident in the British Isles, especially in Ireland and the Isle of Man. In the latter locality, the marl beds containing bivalves of the second or third region in depth, are capped by a great thickness of sands and gravels, occasionally containing littoral shells, but rolled. On these sands the larger boulders usually lie. In Ireland Captain James has found the littoral shells in abundance in the sandy beds, especially in such localities as were evidently close upon the ancient coast line. The period of the extinction, *as a race*, of the reversed variety of *Fusus antiquus* may be referred to that of the upheaval of the Irish sandy beds.

The close of the glacial epoch, ending in this upheaval of the bed of the glacial sea, marks the commencement of a new era in our fauna, and, as we have already seen, of our flora. As a great part of the area, previously occupied by water, now became land, the banishment of a number of species necessarily took place, many of which, in consequence of the change of conditions arising from the causes of their expulsion, retired for ever. The remodelling of our area, which afterwards took place, the formation of the Irish Sea, of the German Ocean, and of a new line of coasts, events calling new influences into play, introduced the existing population of our seas. Part of our glacial testacea had been extinguished, part retired to more congenial arctic seas, and a few disappeared from the coasts of Europe, while they continued inhabitants of the shores of America. A considerable number, however, returned to the seas of their ancestors, where they became and remain the associates of numerous forms, some newly called into being to people the new-formed seas, some coming with favouring currents from the warmer seas of the south. Among the latter were a number of forms which had not always been strangers to the British Seas. During the genial times preceding the glacial epoch, more than fifty species of testacea, inhabitants at present of our seas, lived in them whilst the crag beds were in process of formation but disappeared under the chilly influences of the sub-arctic epoch which succeeded. As either a re-creation (a notion inconsistent with the line of argument I have adopted in this essay) of these forms must have taken place, or else a *re-migration* of them from some distant point where they had lived on, amid favouring conditions, when banished from the British Seas,—an inquiry

whether they may be traced in formations *syn-chronic* with the glacial beds, is of no little interest and geological importance.

Whilst eocene, miocene, and older pliocene marine beds,—represented in our own country by the London clay, and the coralline and red crags, —are found in many parts of the north and middle of Europe and America, the "newer pliocene," such as is typified by the Sicilian tertiaries, those of Rhodes and other parts of the Mediterranean basin, is nowhere present within the area of the *marine* glacial beds, which, on the other hand, are nowhere to be met with within the area of the marine tertiaries of the Sicilian type. The latter, however (as we have already seen), includes a number of characteristic glacial forms which no longer exist in the same marine provinces, but are restricted to the northern or Celtic Seas. It is, therefore, extremely probable—I may say certain—that the glacial formations are "newer pliocene," and the Sicilian tertiaries contemporaneous with the northern drift. As the sea in which those tertiaries were deposited communicated with the glacial seas, we might expect, *à priori*, to find among the relics of that ancient Mediterranean the still-surviving species which had lived in our seas previously to the glacial period, but had retired during its continuance.

The following table will shew that our search has not been in vain:—

Table of British existing Testacea which inhabited our area before the Glacial Epoch, but during it had retired to other seas.

Species.	Formations of Older Date than Northern Drift in which they occur in Britain.	Foreign Newer Pliocene beds in which they occur.
Gastrochæna pholadia.	Coralline and red crags.	Sicily.
Thracia pubescens.	Coralline crag.	Sicily.
Lepton squamosum ?	Coralline crag.	
Pandora margaritacea.	Coralline crag.	
Montecuta substriata.	Coralline crag.	
Montecuta ovata.	Coralline crag.	
Kellia suborbicularis.	Coralline crag.	Sicily.
Lucina rotundata.	Coralline and red crags.	Sicily.
Tellina donacina.	Coralline crag.	S. Italy, Archipelago.
Psammobia vespertina.	Coralline crag.	Sicily, Archipelago.
Psammobia scopula.	Coralline crag.	Sicily.
Psammobia florida.	Coralline crag.	S. Italy.
Cytherea chione.	Coralline crag.	Sicily, Archipelago.
Venerupis irus.	Red crag.	Sicily, Archipelago.
Pullastra virginea.	Red crag.	Sicily.
Venus ovata.	Coralline and red crags.	S. Italy, Archipelago.
Isocardia cor.	Coralline and red crags.	S. Italy, Archipelago.
Cardium nodosum.	Coralline and red crags.	
Arca noæ.	Coralline and red crags.	S. Italy, Archipelago.
Arca raridentata.	Coralline crag.	S. Italy.
Modiola discors.	Coralline crag.	Sicily.
Pinna ingens ?	Coralline and red crags.	
Lima fragilis.	Coralline and red crags.	Sicily, Archipelago.
Lima subauriculata.	Coralline crag.	Sicily.
Pecten tumidus.	Coralline crag.	Sicily.

Species.	Formations of Older Date than Northern Drift in which they occur in Britain.	Foreign Newer Pliocene beds in which they occur.
Emarginula fissura.	Coralline and red crags.	Sicily.
Adeorbis subcarinatus.	Coralline crag,	Sicily.
Scissurella crispata.	Coralline crag.	
Trochus conulus.	Coralline crag.	A. Italy, Archipelago.
Trochus Montecuti.	Coralline crag.	
Rissoa zetlandica.	Coralline crag.	
Rissoa reticulata.	Coralline crag.	S. Italy.
Rissoa striata.	Coralline crag.	
Rissoa vitrea.	Coralline crag.	
Eulima polita.	Coralline and red crags.	Sicily, Archipelago.
Eulima subulata.	Coralline crag.	Sicily.
Scalaria clathatulus.	Coralline crag.	Archipelago.
Chemnitzia elegantissima.	Coralline crag.	Sicily.
Odostomia plicata.	Coralline crag.	Sicily.
Tornatella tornatilis.	Coralline and red crags.	Sicily.
Cerithium tuberculatum.	Coralline crag.	
Cerithium adversum.	Coralline crag.	Sicily.
Pleurotoma lineare.	Coralline and red crags.	Sicily.
Bulla catenata.	Coralline crag.	Sicily.
Bulla lignaria.	Coralline and red crags.	Sicily, Archipelago.
Bulla cylindracea.	Coralline and red crags.	
Bulla truncata.	Coralline crag.	Sicily.
Chiton fascicularis.	Coralline crag.	Sicily.

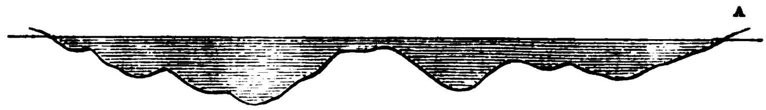
Thus closely are we enabled to track the course of the forms which disappeared for a time from our seas and then returned. A knowledge of the geology of Spain and Portugal, as yet but very partially explored, may show hereafter that their place of refuge was not so far distant as the region into which we have followed them. The currents from the south sweeping the Lusitanian shores, and impinging over our own coasts—as Rennell's current for example—were, probably, and are still, powerful agents in the diffusion of the species, and in bringing about the present mixed condition of our marine fauna. In like manner, currents from the north probably brought back some of the sub-arctic forms so characteristic of the drift. But at certain spots within our area we find assemblages of northern forms so peculiar and so isolated, boreal patches, as it were, that we cannot account for them by any facts connected with the present disposition of the currents, or other transporting influence. These "patches" are especially to be met with in the Clyde district, and among the Hebrides, where they have been explored by Mr. MacAndrew; they have also been observed by Captain Otter, R. N., of Her Majesty's surveying ship Sparrow, on the east coast in the Murray Firth. It is probable there is a similar patch somewhere near the Nymph Bank on the east coast of Ireland, and another in the German Ocean. They have, usually, for their centre, a hole or valley of considerable depth, from 80 to beyond 100 fathoms. Their inhabitants are decidedly of more northern character than the members of the

Celtic fauna, and the species are such as are assembled together far to the north on the coast of Norway. Among them are many of the most remarkable of the forms, found fossil, in the glacial beds, as *Cemoria noachina, Trichotropis borealis, Natica groenlandica, Astarte elliptica, Nucula pygmæa*. These are associated with *Terebratula caput serpentis, Crania norvegica, Emarginula crassa, Lottia fulva, Pecten danicus, Neæra cuspidata, costata* and *abbreviata*, and many peculiar echinoderms and zoophytes, which are either species known only far north, or found only at considerable depths in localities farther to the south.

As these northern "outliers"—a term which well expresses their character—occur in districts which are remarkable for the number and extent they present of upheaved glacial sea-bottoms, their depth and contents have suggested the following explanation:—

When the bed of the glacial sea was upheaved, that upheaval, as we have already seen, raised above water only such portions of it as had been formed in a moderate depth. Such tracts of that sea as were of moderate depth, and consequently inhabited by a peculiar fauna, would still remain below water, though changed in level. A portion of their fauna,—whose organization might be too delicate to endure the sudden change of conditions,—would be destroyed; but another portion, consisting of such species as had greater capacities for vertical range, would survive; for in the deeper parts of the seas of our area, conditions of temperature would still remain such as were required by these isolated northern forms. Let A, of the following diagrams, repre-

A



sent the conformation of a part of the British Seas during the Glacial epoch, throughout their area, of which a boreal or subarctic fauna prevailed; at the close of that epoch the elevation of the sea-bed, whilst it converted into dry land its shallower portions, left the deeper tracts (which within our area were few in number and small in extent) still under water (diagram B). In these depths the arctic forms would still

B

live on, whilst climatal changes would so alter the zoological character of the shallows of our seas (as represented in the unshaded portions of water in figure B), as to isolate the assemblages of animals in the depths, and leave them, as it were, in the condition of northern outliers.

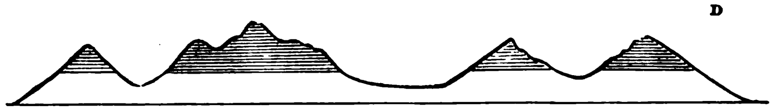
This isolation of the northern marine animals, and restriction of them

to the depths of our seas, is exactly comparable to the change in our flora, brought about by the same geological events. During the Glacial epoch, the group of islands now forming the mountains of Britain, were doubtless clothed with a vegetation correspondent in character to the northern and Scandinavian assemblage of marine animals which then inhabited the surrounding sea (diagram C). The origin of this flora has

C

been inquired into in the earlier part of this essay. The subsequent change of level converted these islands into mountain summits, on which the original flora was preserved and isolated (diagram D), whilst

D



new and warmer climatal conditions introduced over the middle and low ground a vegetation of a more temperate character to become the general flora of the new-formed land.

I have already shown that in the law of representation by plants of latitudes by zones of elevation, the element of *representation* has been confounded with that of *identity*. If this be true in the vertical distribution of terrestrial creatures, it should also be true with respect to that of marine, which I have elsewhere shown* obey a similar law in their vertical distribution, representing parallels of latitude by zones of depth. This I have demonstrated in the case of the Ægean mollusca.

The deepest of the submarine localities, which may be considered as Arctic outliers, with the fauna of which I am acquainted, is one in Loch Fyne, examined by Mr. MacAndrew and myself on the 16th of August, 1845. The dredge brought up eight species of testaceous mollusca, one crustacean, and two echinoderms. So small a number of species among the contents of a full dredge is remarkable and rare, and itself a fact indicative of great depth. Of these mollusca five species were alive. One, a minute species of *Rissoa*, was new; and had been previously taken by Mr. MacAndrew in the British Seas, but only at great depths. The remaining four were *Nucula nuclea* (a northern variety), *Nucula tenuis*, *Leda minuta*, and *Lima subauriculata*. Of these the number of examples of *Nucula tenuis* and *Leda minuta* exceeded greatly those of their companions; they are both essentially northern and Arctic forms, ranging

* Report on the Ægean Invertebrata.

from Greenland to the Scottish Seas, and not known south of Britain. The *Nucula nuclea* and the *Lima* range from Greenland to the Mediterranean, but the variety of the former taken is confined to northern seas, and the latter is very rare, and only found at great depths in seas south of Britain. The dead mollusks taken were *Abra Boysii*, a species of similar range with *Nucula nuclea*, *Cardium Löveni*, a Scandinavian species, and *Pecten danicus*, a Norwegian species, found only in the British Seas in the lochs of the Clyde, and there rarely alive, though dead valves are abundant, *as if the species thus isolated were now dying out*. The echinoderms were *Ophiocoma filiformis*, and *Brissus lyrifer*, the former a Norwegian species; the latter ranging to the Arctic Seas, but southwards not known beyond the Clyde region. The Crustacean was new, both as to genus and species. It will be observed, that the *assemblage* of animals thus taken at this great depth, was *essentially Arctic*. Subsequently we added to the list three species of *Neæra*, *N. costellata, N. rostrata*, and *N. abbreviata*. Of these the second ranges throughout the European Seas. All three are known inhabitants of the Mediterranean, where they are found *associated* only at very great depths. All three are inhabitants of the coasts of Norway, where they have been observed by Professor Löven.

Deep dredgings elsewhere on the British coasts yielded similar results, the assemblages of deep-sea species presenting a decidedly boreal character, and maintaining the representation of the faunas of northern latitudes, mainly through identical species.

In the deepest of the regions of depth in the Ægean, this representation of a northern fauna is maintained, partly by identical and partly by representative forms. The three species of *Neæra*, already mentioned, the *Pandora obtusa*, the *Arca pectunculoides*, the *Saxicava rugosa, Pecten similis, Trochus millegranus, Fusus echinatus, Rissoa reticulata,* and *Terebratula cranium*, are instances of the former, whilst *Crania ringens, Abra profundissima, Astarte pusilla, Cardium minimum, Nucula sulcata* and *ægeensis, Leda commutata, Lottia unicolor*, and *Pleurotoma abyssicola* are examples of the latter. The presence of the latter is essentially due to the law [of representation of parallels of latitude by zones of depth], whilst that of the former species depended on their transmission from their parent seas during a former epoch, and subsequent isolation. That epoch was doubtless the Newer Pliocene, or Glacial Æra, when the *Mya truncata*, and other northern forms, now extinct in the Mediterranean, and found fossil in the Sicilian tertiaries, ranged into that sea. The changes which there destroyed the *shallow-water* glacial forms, did not affect those living in the depths, and which still survive.

In the preceding observations on the marine zoological phenomena, presented by the drift, I have strictly confined myself to evidence derived from beds of the same age, and universally recognised as typically belonging to the "northern drift," properly so called, *i. e.*, formations of the Glacial epoch. There are, however, two English formations containing marine shells, many of them characteristic glacial species, the synchronism of which, with the glacial beds of the north-east of England, of Scotland, and Ireland, has not been granted, or has been received with a doubt. These are the beds at Bridlington and the marine parts of the mammaliferous crag.

The discovery in the Irish drift of several of the most characteristic testacea of the mammaliferous crag, not elsewhere observed in glacial beds, has thrown a new light on the nature of both the English deposits of doubtful age, and enables us, without much misgiving, to refer them to the glacial epoch, and to regard them as probably marking its commencement before the severer climatal conditions had set in. We have seen already that in the red crag certain boreal species appear. In the mammaliferous crag the number of these increases, and the number of the southern forms materially decreases. The following analysis of the valuable catalogue of mammaliferous crag shells, included in the lists of Mr. Searles Wood, will show the state of our testaceous fauna on the eastern province of the British region during the period when that formation was deposited.

They consist, 1st, of species now living in the British Seas, and found fossil in true glacial beds. Those marked with an asterisk are elsewhere in contemporaneous beds, either confined to, or chiefly found in, the Irish drift.

**Pholas crispata.*
**Solen siliqua.*
Mya arenaria.
Lutraria Listeri.
Mactra solida.
Abra Boysii.
Corbula nucleus.
Saxicava rugosa.
Tellina solidula.
**Donax trunculus.*
Astarte borealis.
Astarte compressa.
Cyprina islandica.
Venus fasciata.
Cardium edule.
Pectunculus pilosus.
Nucula tenuis.
Mytilus edulis? (antiquorum).
Pecten opercularis.
Pecten obsoletus.
Velutina lævigata.
Littorina littorea.
Turritella terebra.
Purpura lapillus.
Murex erinaceus.
Fusus antiquus, and var.* *contrarius.*
Pleurotoma rufa.
Pleurotoma turricula.
Natica monilifera? (catenoides of Wood).

2. Of living British species usually regarded as Northern, but not observed hitherto in glacial beds.

Velutina elongata.	*Rissoa semistriata.*
Natica helicoides.	*Rissoa subumbilicata.*

3. Of living British species not found fossil in typical glacial beds, but occurring in contemporaneous Italian newer pliocene strata.

Mactra stultorum.	*Tellina crassa.*
Mactra subtruncata.	*Tellina fabula.*
Lucina radula.	*Bulla obtusa ?*

4. Of species not now known in the British Seas, but still living in the Mediterranean. Not fossil in drift beds elsewhere.

Cardita corbis.

5. Of glacial species of Arctic origin; with the exception of the first, not now living in, or doubtful inhabitants of, the British Seas.

Terebratula caput serpentis.
Scalaria groenlandica var. *similis.*
Tellina calcarea (vars. *obliqua, prætenuis* and *ovata*).
Nucula oblongoides (*hyperborea*).

6. Of extinct crag forms, those marked with an asterisk, are new species of Mr. Wood.

Mya lata.	**Astarte pisiformis.*
Mactra arcuata.	*Nucula Cobboldiæ.*
**Abra obovale.*	*Lottia parvula.*
**Loripes undularia.*	*Cerithium punctatum.*
**Lucina gyrata.*	

From the beds at Bridlington, Mr. Lyell* enumerates 35 species of testacea, of which 20 were living forms, and 26 species common to the mammaliferous or Norwich crag. I have had an opportunity of examining a collection from this locality belonging to my friend Mr. Bowerbank, who, with his accustomed liberality, has permitted me to make use of it. It includes 28 species. Of these, *Dentalium entalis, Aporrhais pespelicani, Littorina littorea, Turritella terebra, Buccinum undatum, Anomia ephippium?, Saxicava rugosa, Astarte compressa, Tellina solidula, Pleurotoma turricula,* and *Balanus balanoides*, are common living British species known also as fossils in most glacial beds.

Trichotropis borealis, Natica groenlandica, Fusus Sabini and *Astarte borealis*, are rare North British species of Arctic origin.

Fusus fornicatus and *scalariformis, Tellina groenlandica*, are Arctic and Boreal American species, the first extremely rare, the others not now living in the British Seas.

* Magazine of Natural History, vol. xii. p. 324.

Cancellaria costellifer is a species, found fossil in the red crag, not now known living in the European Seas, but still surviving on the coasts of North America.

These are accompanied by *Nucula Cobboldiæ*, and by *Cardita scalaris*, a crag species now extinct, and probably representative of the existing *Cardita arctica*. With them are a species of *Astarte* and a *Natica*, both new to me.

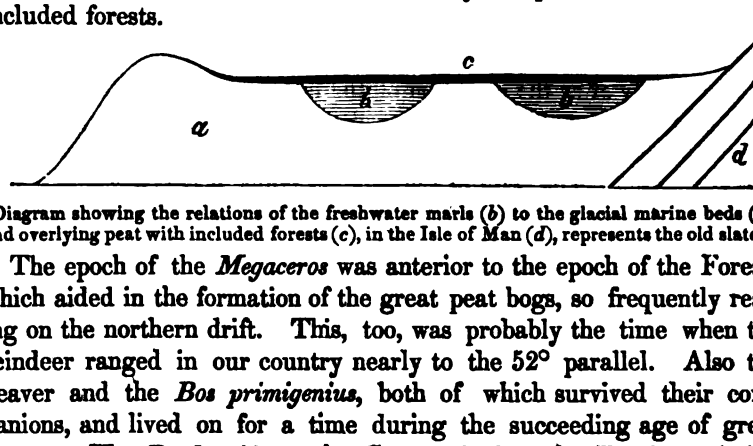
The examination of the Bridlington fossils has convinced me that they are truly of the age of the mammaliferous crag, and that both those formations may be referred to the epoch of the Northern Drift, and probably—especially the last mentioned—to the commencement of that epoch before the severer conditions had set in. This view is borne out by the presence of *Cyrena trigonalis** and *Paludina unicolor* (freshwater mollusks still surviving in southern regions) in freshwater beds containing mammals which do not appear after the drift along with mollusks which are common living British species now. These freshwater formations (as that of Gray's in Essex) are probably contemporaneous in part with the marine strata of the red crag. If, as I am informed by Mr. Trimmer, the Norwich crag marine beds of Bramerton alternate with freshwater beds, local phenomena of elevation and depression are indicated during the commencement of the Glacial epoch, which would account for the disappearance of some of the peculiar forms in the Norwich crag, whilst the extinction of *Nucula Cobboldiæ*, the *Cancellaria* and the *Cardita*, all local species, was evidently due to the conversion of the area of the crag seas into sand.

Immediately after the elevation of the bed of the great glacial sea, a great part of the area now occupied by the Celtic province of the European Seas must have been in the condition of dry land, forming extensive plains. The state of the existing fauna of the German Ocean, as compared with the fauna of that portion of our area during the Crag epochs and the commencement of the Glacial epoch, proves that the change was such as to destroy the ancient population of that sea,—doubtless through the conversion, probably gradual, of its bed into land. How far northwards this land extended it is now impossible to say, but we find the fragments of it bordering the seaside, even to the farthest parts of the mainland of Scotland. It linked Britain with Germany, Iceland, and Denmark; and a corresponding plain united Ireland with England. When considering the distribution of our flora, we derived our Germanic plants and animals from the mainland of Europe, across this ancient land. Whether the breaking up of it was slow or rapid, it

* This species is found fossil in the Sicilian Newer Pliocene beds. It does not appear to differ essentially from the common living *Cyrena* of the Nile.

is impossible to determine, but judging from the effect of the sea in destroying the portions which remain, we may suppose that it was rapidly effected in some places, and at certain times.

That the climatal conditions of the area thus converted from sea into land, were not suddenly but gradually altered, is shown by fair evidence. In the beautiful volume on the history of our Fossil Mammalia and Birds, by Professor Owen, we have an immense mass of invaluable information on the distribution of our ancient land-animals brought together. If we select from this treasury of palæontological knowledge the portions which concern the area and epoch under discussion, and lay down on our map the ranges of those of our quadrupeds which distinctly inhabited Britain after the Glacial epoch,—and in this category I would include most of the cave-animals,—we shall see distinct indications of climatal conditions prevailing over a great portion of that area very different from those now existing. The position of the remains of the *Cervus megaceros* in basins of freshwater marls, containing existing testacea, resting in depressions of the upheaved glacial sea-bed (as in Ireland and the Isle of Man), gives a clue to the prevailing condition during the earliest post-glacial times. We cannot suppose that the limited tract of drift forming the northern extremity of the Isle of Man, in which there are numerous freshwater basins, containing entire skeletons of the *Megaceros*, was other than portion of a larger region inhabited by that remarkable deer. Now these basins are distinctly, both in the Isle of Man and Ireland, overlaid by the peat, with its ancient included forests.



[Diagram showing the relations of the freshwater marls (*b*) to the glacial marine beds (*a*), and overlying peat with included forests (*c*), in the Isle of Man (*d*), represents the old slates.]

The epoch of the *Megaceros* was anterior to the epoch of the Forests which aided in the formation of the great peat bogs, so frequently resting on the northern drift. This, too, was probably the time when the reindeer ranged in our country nearly to the 52° parallel. Also the beaver and the *Bos primigenius*, both of which survived their companions, and lived on for a time during the succeeding age of great forests. The *Bos longifrons*, the *Cervus elaphus*, the *Elaphus primigenius*, the horse, the wolf, and probably the bear, ranged over a great part of the British area during the intermediate time, and had become generally distributed before the breaking-up of the great central plain, occupying the position of the existing Irish Sea. When the land became covered

by forests, a portion of Britain became included within the ranges of the hyenas, tigers, rhinoceros, aurochs, and their numerous associates, some now altogether extinct, some still existing, though not found in Britain, and some yet numbered among our indigenous quadrupeds.

To this epoch may be referred such an association of extinct mammalia, with freshwater shells, all at present existing, observed by Professor Phillips in Yorkshire.

Many of these animals probably inhabited some portions of the area under review; especially the south-eastern and western parts during the epoch of the Red Crag, and at the commencement of the Glacial epoch, contemporaneously with the associations of existing and extinct or southern forms of freshwater mollusca met with in the freshwater lake deposits of Essex, and the neighbouring counties, and equivalent in part to the marine formations of the mammaliferous crag. As the climate became severer, such species may have retired, and on a favourable change of conditions have again returned to their ancient haunts, —just as we have found the testacea to have done in the neighbouring seas, under the same circumstances. Thus in England, even as Mr. Lyell has observed in the case of the mastodon in America, we have the same species of *Elephas*, *Rhinoceros*, *Felis*, *Canis*, *Equus*, and other genera, both before and after the drift, in the former cases accompanying species (as the *Mastodon angustidens*, and the *Cyrena*), which were never to reappear; in the latter being present during their last days, as it were, at the first birth and in-coming of creatures destined to take their places. The same probably happened with the plants. Mr. Trimmer assures me of the existence of ancient forests of oak and pine distinctly below the drift, yet equivalent to the mammaliferous crag beds. Mr. Lyell quotes the authority of Mr. Robert Brown, for the existence of the spruce (*Pinus abies*) in similar ancient forests on the coast of Norfolk. The latter tree no longer ranges to our islands. It has retired to the far north.

We have seen that a parallel with the conditions of the fauna of the European Seas during the Glacial epoch is now to be met with on the coasts of Boreal America—that on the eastern shores of the New World between the 40th and 60th parallels of north latitude a Boreal fauna, corresponding to that of the Scandinavian and Arctic Seas of Europe meets, without an intervening assemblage of animals comparable with that of our Celtic province, a fauna equivalent to that of the southern European Seas. The point of meeting in America marks the point of cessation of the influence of the cold currents from the Arctic Seas on the one hand and that of the warm gulf-stream on the other. It corresponds to a similar state of things in the vegetation of the neighbouring mainlands, for it indicates the northern limits of the fourth botanical

region of Professor Schouw (that of *Solidagos* and *Asters*), equivalent to the great Mediterranean flora (the third province, that of *Labiatæ* and *Caryophylliæ*, in Schouw's arrangement)—and the southern bound of the characteristic flora of Labrador, which is equivalent to that of Northern Scandinavia; there being no intermediate flora equivalent to the Germanic in Europe. It indicates, in like manner, the point of meeting of two great zoological regions, the one northern, the American province of fur-bearing animals, the European equivalent of which must be sought in the north of Scandinavia—the other southern and characterized through a great part of its extent by the presence of the opossum (*Didelphus virginiana*), and the racoon (*Procyon lotor*); there being no intermediate mammalian province comparable with that of which the wild cat and the mole are typical in Europe. The distribution of the great marine mammals corresponds; the region of habitual haunt of whales, of the range of the walrus, *Phoca leporina* and *Phoca groenlandica*, corresponding in the American Seas to the extension southwards of the Boreal American zoological and botanical land provinces and extending many degrees south of the ranges of the same animals in the European Seas. It is remarkable that the southern limit of the occasional range of whales in the European Seas, corresponds to that of the newer pliocene deposits containing Arctic fossils—doubtless their ancient habitual range.*

The great Boreal American land province is a tract including the Canadas, Labrador, Rupert's Land and the countries northwards. It equals Europe in extent. Its zoological features have been investigated by Sir John Richardson, its botanical by Mr. Robert Brown and Sir William Hooker. Both zoologically and botanically it is divisible into two great regions. The northern, known to the hunters as the "barren grounds," is a treeless tract extending from Hudson's Bay in the 60th parallel of north latitude to the great Bear Lake in the 65th. It corresponds to the American division of Schouw's first botanical province. The southern division is wooded (*Pinus microcarpus* and *Pinus Banksiana* are characteristic trees) and embraces many degrees of latitude presenting a surprising uniformity every where in its ferine inhabitants.†

* The facts respecting the distribution of existing animals and plants in the northern hemisphere, bearing so importantly upon the subject of this essay, which I have attempted thus briefly to sketch out, may be understood much better by the reader if he will consult maps 1 and 4 of the phytological and zoological series, in the 'Physical Atlas' of Mr. Johnston and Professor Berghaus. I should be extremely remiss in duty, if I did not take this opportunity of acknowledging my obligations to that admirable and beautiful publication, which, by bringing vividly before the student the leading features of geography, in connexion with meteorology, geology, and natural history, promises to be of incalculable benefit to the progress of the sciences in Britain.

† See Richardson's Report on North American Zoology, in the Reports of the British Association for 1836.

Among the animal population of the barren grounds we find north of the 70th degree the reindeer, the musk ox, a wolf, the Arctic fox, the white bear, the Arctic hare and the ermine and the shrew. Between 60° and 70° most of these animals live associated with the brown bear. The Canadian otter, the American hare, the zibet, *Felis canadensis*, the elk and the *Bos americanus*, most of which are abundant in the wooded region and accompanied there with other species of *Cervus*, *Lepus*, *Meles*, *Vulpes*, *Ursus*, *Felis* and *Lutra*.

It seems to me that we have in these two divisions of the great Boreal American province a parallel to the successive epochs of the fauna of Britain after the upheaval of the bed of the glacial seas—a first when our country was in the condition of the barren grounds, bare and treeless, when the reindeer, the Irish elk, the *Bos primigenius*, lived along with species of bear, fox, wolf, hare, cat and beaver—the assemblage of animals found in the freshwater marl basins below peat; a second when forests of pine, oak and beach overspread the land, and forest-living animals, tree-browsing herbivora, prowling and lurking carnivora, and most, if not all, of our existing indigenous mammals became the population of Britain. The change from the first condition into the second was in all probability gradual and marked by the gradual extinction or retirement of species adapted for the colder, and the introduction of such as were fitted for the more temperate epochs.

In one point our parallel fails us. The great pachyderms which appear to have inhabited Britain after the Drift period, and the assemblage of horses and hyenas have no analogues in the zoological provinces of Boreal America. Every where in the northern hemisphere these remarkable animals appear to have lived during the epoch preceding the historical, and to have become extinct before the advent of man. Their parent region appears to have been Siberia. There they abounded during the last tertiary epoch. Thence they migrated westwards when the regions of the glacial ocean were converted into land. The climatal and geographical conditions which induced their diffusion were but the harbingers of others which led to their destruction. They retired probably to their original specific centres and perished in the land of their origin. From their associates we can judge of their habits, and there can scarcely be a doubt that the ancient elephants and rhinoceroses of Britain and the associated extinct quadrupeds were creatures adapted to severer climatal conditions than those now prevailing in our area, and not like the existing forms of the genera to which they belonged, members of faunas more southern than our own.* Probably the existing zoological features of Northern and Central Asia present the truest

* Consult on this subject the nineteenth chapter of Sir Roderick Murchison's 'Geology of Russia,' and the 'British Fossil Mammalia' of Professor Owen.

analogy with the latest zoological conditions of the west of Europe, including Britain, during the epoch preceding that by common consent of geologists termed *historical*.

Connected with the latest changes included in the *historical* period are the phenomena of raised beaches, properly so called, distinguished by Mr. Smith* from the true glacial beds and containing numerous testacea all characteristic species and *similarly associated* with those now living in the British Seas; and the raised estuary and beach-beds described by Sir Henry De la Beche in the Report on the Geology of Devon and Cornwall. In that work there is described a most interesting section observed by Mr. Henwood at the Carnon Stream Works, where we find sand with sea shells covering the remains of a forest, containing bones of the red deer and human skulls, which rests in turn on tin ground considered by Sir Henry as equivalent to the rhinoceros gravels of Lyme Regis. On the subject of the evidences of the latest changes of level on our southern coasts the essays of Mr. Austen in the Geological Transactions are full of valuable observations.

The agency of man has both added to and diminished the number of our plants and animals. The epochs of the destruction of the wolf and of the beaver are historical events, whilst other more useful creatures have been introduced and naturalized. Even among the invertebrata we find man involuntarily adding to and diminishing the number of our resident species. Now, the draining of lakes destroys the rarer freshwater mollusks, whilst the formation of canals diffuses new forms—as in the case of *Dreissena polymorpha*—all over the country. The progress of cultivation drives before it, and finally banishes, many an indigenous but useful flower, and at the same time introduces others as useless, and perhaps not so harmless, to take its place. With the good comes the evil, and the hand that sows the corn diffuses the dodder. Fortunately the records of natural history have been begun in good time, and the influence of man's agency through the progress of civilization, and its accompaniments, is of too recent action to affect the statistics of our science.

Great as the changes appear to be affecting the disposition of land and water, during recent geological periods, as compared with the present, assumed by me in this essay, I cannot but express my conviction that future research will not only confirm these, but prove that still greater took place during the epochs under inquiry. The phenomena of the glacial formations, the peculiarities in the distribution of the animals of that epoch, and in the relations of the existing fauna and flora of Greenland, Iceland, and northern Europe are such as strongly to impress upon

* 'On the Relative Ages of the Tertiary and Post-tertiary Deposits of the Basin of the Clyde.'—*Geological Transactions*, vol. vi.

my mind, that the close of the Glacial epoch was marked by the gradual submergence of some great northern land, along the coasts of which the *littoral* mollusks, aided by favouring currents, migrated, whilst a common flora became diffused over its hills and plains. Although I have made icebergs and ice-floes the chief agents in the transportation of an Arctic flora southwards, I cannot but think that so complete a transmission of that flora as we find in the Scottish mountains, was aided perhaps mainly by land to the north, now submerged. It is difficult otherwise, too, to account for the cessation of the Arctic *littoral* mollusks in the Scottish glacial beds, and their replacement by other forms in the English and Irish beds of the same epoch. When dredging on the great fishing-banks bounding the Zetland Isles, and forming long ridges, now in fifty and more fathoms below the sea, stretching from some unexplored point in the north, like long arms, down to the Scottish shores, and covered with angular fragments of the rocks of which they are formed, I was strongly struck with their resemblance to the rugged and broken surfaces of the neighbouring islands, and could not divest myself of the notion that these banks were submerged mountain chains. Before, however, this can be fairly assumed, we must have a re-examination of the vegetable and animal productions of Iceland, that great northern centre of volcanic power, the presence of which where it is, is possibly intimately connected with the phenomena we have been endeavouring to interpret.

The chief conclusions to which the facts and arguments stated in this essay lead, may be summed up as follows :—

1. The flora and fauna, terrestrial and marine, of the British Islands and Seas, have originated, so far as that area is concerned, since the meiocene epoch.

2. The assemblages of animals and plants composing that fauna and flora, did not appear in the area they now inhabit simultaneously, but at several distinct points in time.

3. Both the fauna and flora of the British Isles and Seas are composed partly of species, which, either permanently or for a time, appeared in that area before the Glacial epoch, partly of such as inhabited it during that epoch, and in great part of those which did not appear there until afterwards, and whose appearance on the earth was coeval with the elevation of the bed of the glacial sea, and the consequent climatal changes.

4. The greater part of the terrestrial animals and flowering plants now inhabiting the British Islands are members of specific centres beyond their area, and have migrated to it over continuous land before, during, or after the Glacial epoch.

5. The climatal conditions of the area under discussion, and north, east, and west of it, were severer during the Glacial epoch, when a great

part of the space now occupied by the British Isles was under water, than they are now or were before, but there is good reason to believe, that so far from those conditions having continued severe or having gradually diminished in severity southwards of Britain, the cold region of the Glacial epoch, came directly into contact with a region of more southern and thermal character than that in which the most southern beds of glacial drift are now to be met with.*

6. This state of things did not materially differ from that now existing under corresponding latitudes in the North American, Atlantic, and Arctic Seas, and on their bounding shores.

7. The alpine floras of Europe and Asia, so far as they are identical with the flora of the Arctic and sub-Arctic zones of the Old World, are fragments of a flora which was diffused from the north, either by means of transport not now in action on the temperate coasts of Europe, or over continuous land which no longer exists. The deep-sea fauna is in like manner a fragment of the general glacial fauna.

8. The floras of the islands of the Atlantic region, between the Gulf-weed bank and the Old World, are fragments of the great Mediterranean flora, anciently diffused over a land constituted out of the up-heaved and never-again submerged bed of the (shallow) Meiocene Sea.† This great flora, in the epoch anterior to, and probably, in part, during the

* This conclusion is directly opposed to that of the Swiss glacialists. Professor Agassiz writes, in his essay entitled 'A period in the History of our Planet,' (Edinburgh New Philosophical Journal, vol. xxxv.) as follows:—

"A crust of ice covered the superficies of the earth, and enveloped in its rigid mantle the remains of organisms which but a moment before had been enjoying existence on its surface. In a word, a period appeared in which the greater portion of the earth was covered with a mass of frozen water; a period in which all life was annihilated, everything organic was put an end to,—the Glacial period.

"This Glacial period is the epoch of separation betwixt the Diluvial period, as it has been termed by geologists and our present period; it is it which, like a sharp sword, has separated the totality of now living organisms from their predecessors, which lie interred in the sand of our plain, or below the ice of our polar regions; lastly, it is it which has left to our times the testimonies of its former greatness upon the tops, and in the valleys of our Alps—the glaciers."—p. 17.

"The British Islands, Sweden, Norway, and Russia, Germany and France, the mountainous regions of the Tyrol and Switzerland, down to the happy fields of Italy, together with the continent of Northern Asia, formed undoubtedly but *one* icefield, whose southern limits investigation has not yet determined. And as on the eastern hemisphere, so also on the western, over the wide continent of North America, there extended a similar plain of ice, the boundaries of which are in like manner still unascertained. The polar ice, which at the present day covers the miserable regions of Spitzbergen, Greenland, and Siberia, extended far into the temperate zones of both hemispheres, leaving probably but a broader or narrower belt around the equator, upon which there were constantly developed aqueous vapours, which again condensed at the poles," &c.

† I say *never again submerged*, since I am not acquainted with any instance of the meiocenes of Southern Europe and Northern Africa being capped by subsequent marine beds.

Glacial period had a greater extension northwards than it now presents.*

9. The termination of the Glacial epoch in Europe was marked by a recession of an Arctic fauna and flora northwards, and of a fauna and flora of the Mediterranean type southwards, and in the interspace thus produced, there appeared on land the general Germanic fauna and flora, and in the sea that fauna termed Celtic.

10. The causes which thus preceded the appearance of a new assemblage of organised beings, were the destruction of many species of animals and probably also of plants, either forms of extremely local distribution, or such as were not capable of enduring many changes of conditions,— species, in short, with very limited capacity for horizontal or vertical diffusion.

11. All the changes before, during, and after the Glacial epoch, appear to have been gradual and not sudden, so that no marked line of demarcation can be drawn between the creatures inhabiting the same element and the same locality, during two proximate periods.

* In the notes to the first part of his 'Cosmos,' Humboldt quotes a passage in which that wonderful old geographer, Strabo—the accuracy and minuteness of whose observation I have often had occasion to admire when accompanying my friends, Captain Graves and his officers, during their surveying labours on the coast of Asia Minor—distinguishes two kinds of islands, those which have been detached from the mainland, and those which have arisen from the sea. Now, though the islands situated in the region of the Atlantic, between the Gulf-weed bank and the Old World, are in great part of volcanic origin, in each group there are fossiliferous strata of sedimentary origin and meiocene age, all so related to the corresponding beds in Europe that they must be undoubtedly regarded as the fragments of the upheaved bed of an uniform shallow meiocene sea.

In the Madeira group the tertiary limestone, according to Mr. Smith, forms the base rock of the Isle of San Vincente, and in Madeira itself is elevated to a height of 2,500 feet, "a change," writes the observer, "previous to the ejection of the overlying volcanic products." Mr. Smith states also that there are no evidences, in that island, "of elevation f the land during or subsequent to the volcanic period—*though strong indications of subsidence*."—(*Geol. Proceedings*, vol. iii. p. 351.) The meiocene limestone of St. Mary's, in the Azores, which includes *Pecten latissimus*, and other well-marked fossils, will also probably be found, on examination by a competent observer, to be more ancient than the volcanic rocks of that region. In the Canaries and Cape de Verde Islands there are also tertiary marine strata, apparently of meiocene age, and fragments of the same great sea bed with those in the other East Atlantic Islands. That these islands are all, when geologically considered, parts of one system of land, anciently continuous, and belong to Strabo's first class, agrees with their botanical and zoological character as part of one (the great Mediterranean) province. Their floras are all closely related to those of the nearest mainland, and are also mutually related through endemic plants to each other.

Out of 596 species of flowering plants, inhabiting Madeira and Porto Santo, 108 are endemic. Out of the 108, 28 are common to Madeira and the Azores. (List collated by Dr. Lemann, kindly communicated by Dr. Joseph Hooker.) In the Flora Azorica of Seubert, 400 (flowering and flowerless) plants are enumerated, of which 50 are stated to be endemic and peculiar to the Azores, 34 extra-European, including 23 common to the Azores and Madeira, or the Canaries, and 316 European. The Azorean researches of Mr. Hewett Watson (see his papers in the Botanical Magazine) add to and correct this list.

12. The relationship now existing between the faunas and floras of Boreal America and Europe, both marine and freshwater, was established during (probably towards the close of) the Glacial epoch.

13. No glacial beds are known in southern Europe; no "newer pliocene" (in the sense of equivalents of the Sicilian tertiaries), in the centre and north. In the latter we find most of the existing British testacea, which after inhabiting our area before, disappeared from it during the Glacial epoch; and with them we find certain glacial species of northern origin, now extinct in the seas of southern Europe. I infer the synchronism of the glacial and Sicilian deposits.

Throughout this essay I have used the epithet "glacial," in connexion with the words "epoch," "beds," and "formation," in a sense which purists in geological phraseology may consider objectionable. I have used it, however, for want of a better, and as an expression of convenience, always intending to express by the phrase "Glacial epoch" that section of geological time which was typically distinguished by the

A writer, evidently well versed in the subject, in the 'Phytologist,' for March, 1846, sums up our present knowledge of the Azorean flora as follows:—" The number of species absolutely limited to the Azores is rather less than stated by Seubert, while the number of species common to them and to Madeira requires to be taken at a higher figure. Speaking in round numbers, we may say that four-fifths of all the species now wild in the Azores are wild also in Europe, from which many of them have been doubtless carried to the Azores by the early settlers. Of the remaining one-fifth, nearly the whole number are peculiar to the Azores, or to the Archipelago of the Atlantic Islands, which includes also Madeira and the Canaries. Some have emigrated to the Azores from the continents of Africa and America." The floras of Madeira and the Canaries indicate their proximity to the ancient bounds of the great Mediterranean flora, to the ancient subtropical African province, of which the Cape de Verde Isles probably present us with fragments. (For the flora of the Canaries see the great work of Webb and Berthollet.)

In the Gallapagos Islands we have a group which come under Strabo's second class; and, since they lie not farther from the South American mainland than the Azores do from Europe, and moreover have the advantage of lying in the course of a great current (Humboldt's or the Peruvian current) flowing towards them from the American shores, and therefore likely to be a powerful agent in the diffusion of organic forms, they afford us a good opportunity of comparing the features of organic life in islands of the first class with those in such as are distinctly of the second. The researches of Mr. Darwin and of Dr. Joseph Hooker, have furnished good data for such comparison. What is the result? That in these islands, which were never united with the mainland, we have distinct systems of *creatures* related to those of the nearest land, by *representation or affinity*, and not by *identity*. "The natural history of those islands," writes Mr. Darwin, in his admirable 'Journal of Researches,' "is eminently curious, and well deserves attention. Most of the organic productions are aboriginal creations found nowhere else; there is even a difference between the inhabitants of the different islands; yet all show a marked relationship with those of America, though separated from that continent by an open space of ocean between 500 and 600 miles in width. The Archipelago is a little world itself; or, rather, a satellite attached to America, whence it has derived a few stray colonists, and has received the general character of its indigenous productions; considering the small size of these islands, we feel the more astonished at the number of their aboriginal beings, and at their confined range."—(Second Edition, p. 376.)

prevalence of severe climatal conditions through a great part of the northern hemisphere, and during which those marine accumulations, in part truly sedimentary deposits, which have been called "Northern drift," were formed. I have selected the word "glacial," in order to remind the geologists of the ice-charged condition of our seas during that epoch,—conditions which probably did not prevail during its earlier stage, and the gradual disappearance of which marked its conclusion. As, however, it appears almost certain that the "Glacial epoch," and that of the deposition of Sicilian and Rhodian tertiaries were synchronic it would be advisable to adopt some term to express that geological period as a whole, and by which to designate the formations of that period. Mr. Lyell's term, "pleistocene," would, perhaps, best serve the purpose, as that of "newer pleiocene" is not sufficiently distinctive, and may lead to confusion. In this case, among English tertiaries, the coraline crag would rank as *meiocene*, the red crag as *pleiocene*, the glacial beds as *pleistocene*, and the megaceros freshwater marls and marine raised beaches as two stages of *post-tertiary*.

The line of argument I have adopted is equally applicable to the investigation of the relations, geological and palæontological, of the ancient geological epochs, one with another, as of the present with the geological past. If the constancy of species, and the mutual relationship through a common descent, of all the individuals composing each, be granted, this diffusion in time and space will, when traced, furnish us with a new clue to the determination of the configuration of land and water, during the epochs when they existed, and also to the extension or limitation of peculiar climatal conditions, during each period, and to the causes which replaced them by others.

EXPLANATION OF THE DIAGRAMS.

I.—*Diagram of the distribution of British Phanerogamous Plants and Marine Mollusca.*

In this diagram the Roman numerals within circles indicate the terrestrial provinces in which we find the several sub-floras composing the British flora chiefly developed, and the arrows with coloured flukes indicate the directions they took in their migration from the continent. I. is the region of the west Irish flora, or Asturian type. II. is the region of the Devon flora, or Norman type. III. is the region of the Kentish flora, or the north French type. IV. is the region of the Alpine flora, or Scandinavian type. V. is the sign of the great Germanic or central European type, which must be understood as mingled up in the other regions—overspreading, as it were, the country. The orange tint represents I.; the pink, II.; the yellow, III.; the blue, IV., and the green, V.

The marine molluscan faunas are indicated by Roman numerals, not surrounded by circles, and by arrows with barred tails; the number of the bars on the tail of an arrow indicates the number of the type, the direction of which, in the course of its migration, is marked by the direction of the arrow, and the turning point by curved arrows. The types which are non-migratory are indicated by numerals only, and those which are universally distributed over the area represented in the map are omitted.

Diagram II.

In this map I have endeavoured to convey a graphic idea of certain geological, zoological, and botanical features presented by the region of the north Atlantic, either now or at former epochs, and which throw light on the history of the Pleistocene formations, and of our existing fauna and flora.

The space coloured *blue* represents the portion of the northern hemisphere anciently, and in part at present, under the condition of which a glacial or boreal fauna, is characteristic. The *dark blue* represents such a region as now existing; the *pale* and *dark* together indicate the ancient glacial region. Throughout this region an uniform assemblage of marine testacea lived during the glacial epoch. Two-thirds of the same species now live assembled together in the region coloured *dark blue*, including all the forms of northern origin now extinct in the European portion of the *pale-blue* area. The bound of the *dark-blue* region indicates the line within which ice floated in summer, and which is constantly inhabited by the larger cetacea.*
The bound of the *pale-blue* region agrees very nearly with the limit of the occasional range of whales now.

* Consult Chart of the Atlantic Ocean, in Johnston's Physical Atlas.

At the southern bound of the *dark-blue* region a molluscan fauna, equivalent to the Lusitanian on the European side of the Atlantic, meets with one of a Boreal character. A similar feature is presented by the drift fossils of the *pale-blue* region at the point of meeting with the *yellow*, on the European side.

It is to be observed, that within the *blue* region all pleistocene fossiliferous beds contain fossils of the glacial type; and that south of it within the *yellow* the fossils of the equivalent beds are of the Sicilian newer pleiocene type.

The *purple* lines and bounds mark spots and provinces wherein we now find a flora, or the fragments of a flora, of an Arctic or truly Boreal character. It will be observed that in Europe this flora is indicated as fragmentary, and marks the lines of mountain chains, whilst in the new world (within the *dark-blue* line) it indicates constant Boreal regions of vegetation.

The *yellow* marks a region, the greater part of which was probably continuous land between the close of the meiocene epoch and the commencement of the pleistocene. The Gulf-weed bank, repeating the form of the meiocene coasts of the Old World, indicates its Atlantic bounds. Over this region I suppose the Asturian flora to have migrated to Ireland, and afterwards (during the Glacial epoch) to have been isolated, and in great part destroyed. This was a region of shallow sea during the Meiocene epoch, bounded by a gulf of deep water, dividing the marine zoological provinces of the old world from those of the new.

The *lines* of colour mark the regions of existing floras.

1st. The *purple*, already mentioned, marks the region of Arctic and Boreal floras.

2nd. The *orange* encircles the region of the Mediterranean flora, and includes the fragments of the ancient post-meiocene land. During such a condition of things as prevailed during the Glacial epoch (judging from the present state of the opposite side of the Atlantic), the *orange* line then extended farther north, and approached the *purple*, then circumscribing most of the land within the *blue* region.

3rd. The *green* bounds the region of the existing Germanic flora, and includes the space elevated at the close of the Glacial epoch, when the *orange* and *purple* lines receded from each other. The extension of this land included Iceland, where we now find a considerable assemblage of Germanic plants isolated.

APPENDIX.

CATALOGUE OF SPECIES OF MARINE ANIMALS,

The remains of which are found Fossil in Beds of the Glacial Epoch.

[In the following catalogue I have endeavoured to rectify the nomenclature of the species. The principal synonyms are given; the chief localities in which the species are found fossil in formations of the Glacial epoch; their distribution at present in the sea; and a concise geological history of each, so far as the British area is concerned.]

VERTEBRATA.

MAMMALIA.

The following *Cetacea*, probably belonging to beds of this epoch are enumerated by Professor Owen :—

Phocæna crassidens.
Monodon monoceros.
Physæter macrocephalus.
Balænoptera boops.
Balæna mysticetus.

PISCES.*

Mallotus villosus.
LOCALITY, *fossil.* Canada (Mr. Logan).
Loc., *living.* Greenland.

MOLLUSCA.

Brachiopoda.

1. *Terebratula psittacea.* (*Anomia* sp.), Linnæus.
Loc., *fossil.* Ayrshire. Bramerton. (Canada.)
Loc., *living.* Seas of Newfoundland, Labrador, Greenland, and Norway. It is inserted in British lists, on doubtful authority. In a copy in my possession of the "Catalogue of North British Testacea," by Captain Laskey, interleaved and enriched with manuscript notes in the author's handwriting, is the following memorandum :—"*Terebratula psittacea*, Turton. The under valve was found by me on the shore of Aberlady Bay, at low water, and since, a perfect specimen by dredging in the deeps of the Frith of Forth. 20th July, 1825."

2. *Terebratula caput serpentis.*
SYN., *T. aurita*, Fleming, *T. costata.* Lowe.
Loc., *fossil.* Sweden.

* One of the freshwater fishes in the Mundesley beds was identified by Mr. Yarrel with *Esox lucius.* At present the pike is the only freshwater fish common to Europe and America.

Loc., *living*. In local patches (*Boreal*) in the British Seas, chiefly on the coast of Scotland, where it grows to a great size, and is very abundant in particular localities, as Loch Fine. Its usual range is from 15 to 30 fathoms, and it has been taken by Mr. MacAndrew and myself as deep as 80 fathoms, more than 20 miles from the nearest land. It occurs in more northern latitudes on the Scandinavian coast; also in the seas of Boreal America. South of Britain it is apparently confined to very deep water, and has been taken in the Mediterranean.

Note. The great horizontal and vertical range of this species corresponds with its range in time. The *Terebratula striatula* of geologists—a species which commences its range in the upper green sand, and is found in the upper and lower chalk, and in the London clay—appears to be identical with it. Hence it may be regarded as one of the oldest of existing animals.

Order *Palliobranchiata*.

3. *Pholas crispata*, Linnæus.

Loc., *fossil*. In a fragmentary state in the drift beds of Ireland. With the valves united and *in situ* at Bridlington. In the mammaliferous crag at Postwick, near Norwich. [Sweden.]

Loc., *living*. In the northern and Celtic regions of the European Seas, and on the coasts of Boreal America and the United States, as far south as Carolina (De Kay). A member of the littoral zone.

Note. An inhabitant of the British Sea, during the epochs of the Red and Coralline Crags.

4. *Solen siliqua*, Linnæus.

Loc., *fossil*. In the Clyde beds, the Irish drift, and the mammaliferous crag at Bramerton.

Loc., *living*. In all the European Seas. Littoral.

Note. Appeared in the British Seas during the epoch of the Red Crag.

5. *Solen ensis*, Linnæus.

Loc., *fossil*. In the Irish and Lancashire drift.

Loc., *living*. Throughout the European Seas, and on the coast of Boreal America. Littoral.

Note. Fossil in the Belgian Crag, according to Nyst.

6. *Panopæa arctica* (*Glycimeris* sp.), Lamarck.

Syn., *P. Aldrovandi* of British authors. *P. Bivonæ* of Phillippi, and of Mr. Smith's catalogue. *P. norvegica* of the mineral conchology. *P. Spengleri* of Valenciennes.

7. *Mya truncata*, Linnæus.

Loc., *fossil*. Frequent in the clays and sands of the British drift, occurs *in situ*, with united valves in the Clyde district. The short variety (var. *Uddevallensis*) is found in the Clyde beds. Both varieties are found in the glacial formations of Scandinavia, Russia, and Canada.

Loc., *living*. In the Celtic and northern seas of Europe, the seas of Greenland and of Boreal America, as far south as Cape Cod. The short variety is now found living in the Gulf of St. Lawrence (Captain Bayfield), but

is not known on the European shores. The range of *Mya truncata* in depth is much beyond that of *Mya arenaria*. It inhabits the littoral, laminarian and coralline zones on the coasts of Britain.

Note. Mya truncata appeared in the British Seas during the epoch of the Coralline Crag, and has inhabited their area ever since. During the Glacial epoch it extended its range to the Mediterranean region, where it is now extinct. *Sphenia Swainsoni* is the young of *Mya ovalis*, of Turton, the half-grown shell.

Loc., *fossil. In situ* with both valves united in the Clyde beds.

Loc., *recent.* Very rare in the British Seas. More frequent in the Arctic Seas of Europe, and those of Boreal America.

Note. Appeared in the British Seas during the epoch of the Red Crag. During the Glacial epoch it extended its range to the Mediterranean region, where it is now found fossil in the Sicilian tertiaries.

8. *Mya arenaria*, Linnæus.

Loc., *fossil.* Generally distributed through the British glacial beds. In the mammaliferous crag at Bramerton. [Sweden, Canada].

Loc., *recent.* The seas of northern and Celtic Europe; of Greenland and of the coasts of Boreal America, as far south as New York.

Note. Appears in the British during the epoch of the Red Crag. It is found fossil in the Campinian beds of Belgium, according to M. Nyst.

9. *Mya lata*, Sowerby.

Loc., *fossil.* In the mammaliferous crag of Bramerton.

Note. It is found among the red crag fossils, but it is not known living.

10. *Mactra stultorum*, Linnæus.

Syn., *Mactra magna*, Woodward.

Loc., *fossil.* Mammaliferous crag at Thorp.

Loc., *living.* Generally distributed through the European Seas, and according to Phillippi, it inhabits the Red Sea.

Note. Appeared in our own area during the Red Crag epoch.

11. *Mactra solida*, Linnæus.

Syn., *Mactra dubia* and *M. ovalis*, Sowerby.

Loc., *fossil.* General in the sands and clays of the drift. Mammaliferous crag of Thorpe.

Loc., *living.* All the European Seas.

Note. Occurs in both red and coralline crags; also in the Campinian beds of Belgium.

Mactra striata of Mr. Smith (Wern. Trans., vol. viii. pl. 1. f. 22) appears to be a variety of this.

12. *Mactra truncata*, Montagu.

Loc., *fossil.* In the Forth beds (of the Glacial epoch?).

Loc., *living.* The British Seas.

13. *Mactra subtruncata*, Montagu.

Syn., *Mactra cuneata*, Woodward.

Loc., *fossil.* In the mammaliferous crag at Thorpe. In the Forth beds.

Loc., *living.* In the British and Northern Seas.

Note. Appears in the red crag.

14. *Mactra arcuata*, Sowerby.

Loc., *fossil*. In the mammaliferous crag.

Note. Not known living. Appeared in the British Seas during the Coralline Crag epoch, and lived through that of the Red Crag.

15. *Lutraria elliptica*, Lamarck.

Syn., *Mactra lutraria*, Linnæus. *Lutraria vulgaris*, Fleming.

Loc., *fossil*. In the Irish and Lancashire beds.

Loc., *living*. In the Celtic and Southern regions of the European Sea.

Note. It is found fossil anterior to the Glacial epoch in both coralline and red crag, and in the Campinian beds of Belgium.

16. *Scrobicularia piperata* (*Mactra* sp.), Gmelin.

Mactra Listeri and *piperata*, Gmelin.

Syn., *Mactra compressa*, Montagu. *Lutraria compressa* and *piperata*, Lamarck. *Tellina plana*, Donovan. *Lutraria Listeri*, S. Wood. *Amphidesma compressum*, Fleming.

Loc., *fossil*. In the mammaliferous crag at Bramerton.

Loc., *living*. Throughout the European Seas.

Note. Appeared in our area during the Red Crag epoch.

17. *Thracia declivis* (*Mya* sp.), Pennant.

Syn., *Anatina convexa*, Turton. *Amphidesma convexum*, Fleming.

Loc., *fossil*. In clay beds at Belfast *in situ*.

Loc., *living*. The British Seas.

18. *Abra alba* (*Mactra* sp.), Wood.

Syn., *Ligula Boysii*, Montagu. *Amphidesma album*, Fleming. *Erycina Renieri*, Bronn.

Loc., *fossil*. Clyde beds, Dalmuir. Mammaliferous crag at Bulcham.

Loc., *living*. Throughout the European Seas, inhabiting the second and third zones of depth.

Note. Commences its range in the coralline crag.

19. *Abra prismatica*. (*Ligula* sp.), Montagu.

Loc., *fossil*. Greenock (Mr. Smith).

Loc., *living*. Throughout the European Seas, but chiefly in the north.

Note. Mr. Searles Wood records it as a fossil of the coralline crag.

20. *Abra intermedia*, W. Thompson.

Syn., *Amphidesma obovale*, S. Wood.

Loc., *fossil*. Mammaliferous crag of Southwold.

Loc., *living*. North and west of Ireland, and coast of Scotland. Denmark.

Note. Appears first in the red crag.

21. *Montacuta bidentata* (*Mya*, sp.), Montagu.

Loc., *fossil*. A Bridlington fossil, in Mr. Bowerbank's collection, appears to belong to this species.

Loc., *living*. European Seas (and coasts of Boreal America?).

22. *Corbula nucleus*, Lamarck.

Syn., *Corbula striata*, Fleming. *Mya inæquivalvis*, Montagu. *Corbula rotundata*, Sowerby (Min. Conch.).

Loc., *fossil.* Scottish and Irish glacial beds. In the mammaliferous crag at Bramerton.

Loc., *living.* Throughout the European Seas.

Note. Fossil in the coralline and red crags.

23. *Saxicava rugosa* (*Mytilus* sp.), Linnæus.

Syn., *Hiatella rugosa*, Fleming. *Saxicava pholadis* of Lamarck; *Solen minutus* of Linnæus; *Hiatella oblonga* of Turton; *Hiatella arctica* of Lamarck, and *Mytilus præcisus* of Montagu, are all varieties of this protean species. *Agina purpurea* of Turton appears to me to be a form of the young shell.

Loc., *fossil.* One of the most generally distributed shells in the glacial beds. It occurs in all the Irish, Scotch, and English fossiliferous drifts and glacial clays, including the Bridlington beds and the mammaliferous crag of Thorpe. Abroad it is found in the glacial formations of Scandinavia, Russia, and Canada.

Loc., *living.* In all the seas of Northern and Arctic Europe, Boreal America, and Greenland. It ranges as far south as the Canary Isles, (d'Orbigny). Its vertical range is very great. In the British Seas it is found abundantly in the laminarian and coralline regions. In the Mediterranean I have observed it alive at all depths between twenty and eighty fathoms.

Note. Saxicava rugosa appears in all its forms in the coralline, and afterwards in the red crag.

24. *Saxicava sulcata*, Smith.

Loc., *fossil.* In the Clyde, Swedish, and Canadian beds.

Loc., *living.* Is not this the Greenland *Mya byssifera* of Otho Fabricius? It is possibly only a variety of the last.

25. *Psammobia feroensis* (*Tellina* sp.), Gmelin.

Loc., *fossil.* In the Lancashire and Irish drift. Always rare.

Loc., *living.* In the beds of Northern and Celtic Europe, frequent. Rare in the Mediterranean.

Note. Occurs in the coralline crags; also in the Campinian beds of Belgium, according to M. Nyst.

26. *Donax trunculus*, Linnæus.

Loc., *fossil.* In the Irish beds. In the mammaliferous crag at Bramerton.

Loc., *living.* Throughout the Celtic and South European Seas, ranging to Senegal (Adamson). Phillippi mentions it among the Red Sea shells collected by Von Hemprich and Ehrenberg. It is always littoral.

Note. The earliest appearance of *Donax trunculus* in the British area dates from the epoch of the Mammaliferous Crag. It is among the species marked by Phillippi as very rare in the Sicilian tertiaries.

27. *Tellina crassa.* Gmelin.

Syn., *Tellina obtusa*, Sowerby (Min. Conch.). *Arcopagia crassa*, Brown.

Loc., *fossil.* Mammaliferous crag at Portwick. Some fragments from the Irish beds appear to belong to this species.

Loc., *living*. The Celtic Seas.

Note. Fossil in both coralline and red crag. It inhabited the Mediterranean region during the Glacial epoch, and is found fossil in the Sicilian tertiaries, but no longer exists so far south.

28. *Tellina tenuis*, Pennant.

Loc., *fossil*. In the Scotch beds.

Loc., *living*. Throughout the European Seas. Always littoral, or nearly so.

Note. Appears to date its origin from the Glacial epoch.

29. *Tellina balthica*, Linnæus.

Syn., *Tellina solidula* of British authors.

Loc., *fossil*. Dalmuir. Frequent in the Irish and western English beds; Isle of Man, Bridlington, mammaliferous crag of Bramerton. [In the Scandinavian beds.]

Loc., *living*. Throughout the European Seas. In the Black Sea (Krynicki).

Note. First appeared during the Glacial epoch.

30. *Tellina groenlandica*, Beck.

Loc., *fossil*. Bute. (Russia, Canada.)

Loc.; *living*. Arctic Seas, Icy Cape. Gulf of St. Lawrence (Captain Bayfield).

31. *Tellina calcarea*, Gmelin.

Syn. *T. proxima*, Brown. *T. ovalis*, Woodward. *T. ovata* and *obliqua* of the Mineral Conchology, and *T. prætenuis* of Woodward appear to me to be varieties of this species.

Loc., *fossil*. Clyde beds. The varieties in the mammaliferous crag at Bramerton and Portwick. [Sweden, Russia, Canada.]

Loc., *living*. In the Arctic Seas [Deshayes]. Behring's Straits [G. B., Sowerby]. Greenland [Möller].

Note. *T. obliqua*, begins in the coralline, the other varieties in the red crag.

32. *Tellina fabula*, Gmelin.

Loc., *fossil*. Mammaliferous crag of Southwold.

Loc., *living*. Throughout the European Seas.

33. *Lucina flexuosa* (*Tellina* sp.), Montagu.

Syn. *Venus sinuosa*, Donovan. *Lucina sinuosa*, Lamarck. *Cryptodon flexuosum*, Turton. *Ptychina biplicata*, Phillippi.

Loc., *fossil*. Clyde beds (*in situ*).

Loc., *living*. Abundant in the seas of Northern Europe. British Seas. Rare in the Mediterranean. Greenland. Seas of Boreal America.

Note. The Mediterranean variety differs slightly from that found in the Atlantic, and resembles the form fossil in the coralline crag. Nyst includes in this species the "*Axinus angulatus*," of the Mineral Conchology, a London-clay fossil, which is certainly distinct, though nearly allied. Two fossils were figured in the Mineral Conchology as species of the genus *Axinus* —the *Axinus obscurus* (Min. Conch., t. 314), a magnesian limestone fossil, and the eocene *Lucina* of the subgenus *Cryptodon*, figured as *Axinus angu-*

latus (Min. Conch., t. 315). Mr. King, of Newcastle, has constituted a genus under the name of *Schizodus* for the former, but as the latter belongs to a known genus, and the former was the type of the Sowerbian genus *Axinus*, that name cannot be superseded by *Schizodus*.

34. *Lucina radula* (*Tellina* sp.), Montagu.

SYN., *Venus borealis*, Pennant. *Venus spuria*, Dillwyn. *Lucina antiquata*, Sowerby (M. C.).

Loc., *fossil*. Ireland? In the mammaliferous crag at Thorpe [Sweden].

Loc., *living*. In the Scandinavian and British Seas (frequent). Rare in the Mediterranean [Phillippi]. Coasts of Boreal America [Gould].

Note. Appears in the British Seas during the epoch of the Coralline Crag. Continued during the Red Crag epoch. In the Campinian beds of Belgium [Nyst]. Common in the Mediterranean region during the Newer Pliocene epoch.

35. *Lucina undularia* (*Loripes* sp.), Searles Wood (MSS.).

Loc., *fossil*. Mammaliferous crag of Bramerton.

36. *Lucina astartea*, Nyst.

SYN., *Lucina gyrata*, Searles Wood (MSS.).

Loc., *fossil*. Mammaliferous crag of Bramerton.

Note. In the crag of Belgium.

37. *Astarte borealis* (*Venus* sp.), Linnæus.

SYN., *Astarte plana*, Sowerby (M. C.). *Crassina Withami*, Smith and Brown.

Loc., *fossil*. Frequent in the glacial beds of Scotland, Ireland, and the north of England. Bridlington. Mammaliferous crag of Bramerton. [Sweden, Russia.]

Loc., *living*. In the Arctic Seas and on the coast of Boreal America. A single fresh valve was dredged by Mr. MacAndrew and myself in 80 fathoms water, 40 miles to the west of the mainland of Zetland (August, 1845).

Note. Not known in British formations anterior to the Glacial epoch.

38. *Astarte elliptica*, Brown.

SYN. This shell is usually known as *Astarte gairensis*, a MS. name given to it by Mr. Nicol, who first observed the species. It is also the *Crassina ovata* of Brown, which is the more common variety. The *Crassina depressa* of Brown appears to be a third form. [*Astarte sulcata* of Nilson.]

Loc., *fossil*. Every where in the glacial beds of Scotland, Ireland, Wales, and the north of England. [Sweden, Russia.]

Loc., *living*. Scottish and Northern Seas. Very abundant in the lochs of the Clyde district.

39. *Astarte danmoniensis* (*Venus* sp.), Montagu.

SYN. *Crassina danmoniensis*, Lamarck. *Crassina sulcata*, Turton, not of Montagu?) *Astarte scotica* is the young of this species, or a variety in which the margin of the valves is not crenulated. Some conchologists, however, regard the *Astarte elliptica* as the true *A. scotica* of Montagu.

Loc., *fossil*. In the Clyde district, the Isle of Man, Ireland, and the north of England, Bridlington. [Russia.]

Loc., *living*. Throughout the Celtic and Northern Seas.

40. *Astarte* sp.?

Loc., *fossil*. There is a species in the Bridlington beds, resembling the var. *Scotica* of *danmoniensis*, but with more numerous ribs, which I regard as distinct. Is this a smooth-margined variety of the shell which Professor Macgillivray describes from the coast of Aberdeen, and refers to *Astarte sulcata* of Montagu?—*History of Molluscous Animals of Aberdeen*, &c., p. 259.

41. *Astarte compressa* (*Venus* sp.), Montagu.

Syn. *Astarte angulata*, Woodward. *Venus Montagui*, Donovan. *Cyprina compressa*, Turton. *Astarte multicostata*, Macgillivray (non Smith). *Crassina convexiuscula*, Brown.

Var. β (latior). *Crassina multicostata*, Smith. *Astarte compressa*, Macgillivray.

Loc., *fossil*. Frequent in all the glacial formations. Bridlington. Mammaliferous crag of Thorpe. [Sweden, Russia.]

Loc., *living*. Throughout the Northern and Celtic Seas. Seas of Boreal America. The var. β is now especially northern, and in the fossil state is the most abundant form.

Note. *Astarte compressa* appeared in the coralline crag sea.

42. *Astarte pisiformis*, Searles Wood.

Syn., *Astarte trigonella*, Nyst?

Loc., *fossil*. An undescribed species found in the mammaliferous crag of Bramerton, and in the two preceding crag formations. "*Astarte pisiformis* is probably *A. trigonella* of Nyst, pl. 6, f. 18, though his species is not crenulated. It may be a young state, or, what is as probable, a sexual difference." Mr. Searles Wood (*in lit.*).

[43. *Astarte laurentiana*, Lyell.

Described and figured in Mr. Lyell's 'Travels in North America,' vol. ii. p. 150. From the glacial beds of Canada].

44. *Cyprina islandica* (*Venus* sp.), Linnæus.

Syn. *Cyprina maxima*, Searles Wood. *Cyprina vulgaris*, George Sowerby. The identity of this species with *Cyprina æqualis* of the Mineral Conchology has lately been disputed by Professor Agassiz. Extreme specimens of each are certainly easily distinguishable. Mr. Searles Wood, however, regards them as one species, and no naturalist has had such opportunities of forming a correct opinion. In a note to his 'Catalogue of Shells from the Crag,' in the sixth volume of the 'Annals of Natural History,' he remarks:—"The umbo of this (*Cyprina islandica*), from the coralline crag, is a little more produced, and appears to have been a thicker shell than the recent, which is the only difference I can detect, while the specimens from the red crag preserve a sort of intermediate character in that respect." M. Nyst also regards *Cyprina æqualis* as a variety of *C. islandica*.

Loc., *fossil*. Common in the British glacial deposits. In the mammaliferous crag of Southwold. [Denmark.]

Loc., *living*. In the Northern and Celtic Seas, and Seas of Boreal America.

Note. During the Glacial epoch the range of this well known mollusk extended to the Mediterranean region, where it is found fossil in the newer pliocene beds of Sicily (Phillippi).

45. *Cardita scalaris* (*Venericardia* sp.), Sowerby.

Loc., *fossil.* Bridlington beds.

Note. This species lived during both the preceding crag epochs. The existence of a species of *Cardita* in the ancient glacial seas of Europe, is paralleled by the presence of a species of the same genus (*Cardita arctica*) in the seas of Boreal America at the present day.

46. *Cardita corbis*, Phillippi.

Loc. *fossil.* In the mammaliferous crag of Southwold (identified by Mr. Searles Wood). In the Campinian beds of Belgium, according to M. Nyst, and present in both coralline and red crag British formations).

Loc., *living*. The Mediterranean Sea.

47. *Artemis exoleta* (*Venus* sp.), Linnæus.

Syn. *Cytherea exoleta*, Lamarck.

Loc., *fossil.* In the glacial beds of Scotland, Ireland, Isle of Man, and north of England.

Loc., *living*. General in the European Seas. Ranges as far south as Senegal (Adamson), is found in the Red Sea, according to Phillippi.

48. *Artemis lincta* (*Venus* sp.), Pulteney.

Loc., *fossil.* Dalmuir (Mr. Smith.)

Loc., *living*. Celtic and Northern Seas of Europe. The Mediteranean (and Red Sea ?) forms belong to *Artemis lupinus* (*Cytherea* sp.) of Lamarck.

Is not the *Artemis Phillippii* of Agassiz (' Iconographie des Coquilles Tertiaires'), also the last-named species ?

Note. Artemis lincta is enumerated as a Bordeaux fossil by Basterot; but Professor Agassiz maintains that the Bordeaux form is distinct, and names it *A. Basterotii.*

49. *Venus* (*Pullastra*) *decussata*, Linnæus.

Loc., *fossil.* Scotch and Irish beds.

Loc., *living*. Celtic and South-European Seas. A Red Sea shell according to Philippi.

Note. Not known fossil before the Newer Pliocene epoch. Its probable specific centre was then, as now, in the Lusitanian Seas.

50. *Venus* (*Pullastra*) *pullastra*, Wood.

Syn., *Venerupis pullastra*, Fleming. *Pullastra vulgaris*, G Sowerby.

Loc., *fossil.* Clyde beds.

Loc., *living*. Celtic and Scandinavian Seas.

51. *Venus* (*Pullastra*) *aurea*, Linnæus.

Loc., *fossil.* Near Dublin.

Loc., *living*. Celtic and South-European Seas.

Note. Neither of the two preceding species are known in beds of older date than the Newer Pliocene epoch.

52. *Venus (Dosina) fasciata*, Montagu.

SYN., *Venus Brogniartii*, Payraudeau.

LOC., *fossil*. Ireland. Mammaliferous crag of Bramerton.

LOC., *living*. Celtic and South-European Seas.

Note. Appeared in the British Seas during the Coralline Crag epoch, and has continued ever since. It is now, as anciently, chiefly developed in the Celtic region, from part of which it appears to have been banished during the Glacial epoch.

53. *Venus (Pullastra) virginea*, Linnæus.

LOC., *fossil*. Scotland and Ireland.

LOC., *living*. Throughout the European Seas, but most plentiful in the Celtic region.

Note. Occurs in the red crag.

54. *Venus ovata*, Pennant.

SYN., *Venus pectinula*, Lamarck. *Venus radiata*, Brocchi.

LOC., *fossil*. Irish and Scotch beds.

LOC., *living*. Throughout the European Seas, but chiefly abundant in the Celtic and Northern regions. In the Mediterranean it is found for the most part at great depths.

Note. Appeared in our area during the Coralline Crag epoch, and never departed.

55. *Venus verrucosa*, Linnæus.

LOC., *fossil*. Among Captain James's Wexford specimens are worn fragments of a *Venus*, probably of this species ; though it would be difficult to distinguish them from similar portions of the crag *Venus turgida*, or the American *Venus mercenaria*.

LOC., *living*. In the southern part of the Celtic region, and throughout the Lusitanian and Mediterranean provinces, where its true centre seems to be. Philippi enumerates it among Ehrenberg and Hemprich's Red Sea shells. Mr. Webb procured it at the Canaries.

Note. It is not known as a British fossil before the Glacial epoch.

56. *Venus gallina*, Linnæus.

LOC., *fossil*. In the Irish, English, and Scotch beds, especially in such as indicate their having been deposited as sand in shallow water.

LOC., *living*. Throughout the European Seas. In the Black Sea, and, it is said, in the Caspian.

Note. Not known fossil in Britain before the Glacial epoch.

57. *Venus casina*, Linnæus.

SYN., *Venus reflexa* (young shell).

LOC., *fossil* Common in the Manx beds, and also found in Ireland and North of England.

LOC., *living*. Abundant in the Celtic Seas, especially toward the North. Inhabits the South-European Seas, but is very rare, and probably found its way into the Mediterranean during the Glacial or Newer Pliocene epoch, in the sea beds of which it is frequently found fossil. I have found it abundantly

in newer pliocene tertiaries in the Archipelago, where I never dredged a single living or fresh specimen.

Note. It is not known in either of the ancient crags.

58. *Cardium edule*, Linnæus.

Syn., *C. obliquum*, Woodward.

Loc., *fossil.* General in the Scotch, English, and Irish glacial beds. Mammaliferous crag of Bramerton. (Sweden, Denmark, Russia.)

Loc., *living.* General through the European Atlantic, and in the Mediterranean, Black and Caspian Seas. It is not known either in Greenland or Boreal America, being replaced there by *Cardium islandicum.* Its southernmost recorded habitat is the Canary Islands.

Note. Its first appearance in the British Seas was during the epoch of the Red Crag.

59. [*Cardium islandicum*, Chemnitz.

Syn., *Cardium ciliatum*, Otho Fabricius.

Loc., *fossil.* Glacial deposits of Russia and Canada.

Loc., *living.* Arctic and Boreal American Seas].

60. [*Cardium groenlandicum*, Chemnitz.

Syn., *Venus islandica*, of Otho Fabricius, in the Fauna Groenlandica: not of other authors.

Loc., *fossil.* Glacial deposits of Russia and Canada.

Loc., *living.* Arctic and Boreal American Seas.

Note. During the Red Crag epoch this species existed in the British Seas.]

61. *Cardium exiguum*, Gmelin.

Syn., *Cardium pygmæum*, Donovan.

Loc., *fossil.* Stated in Mr. Smith's list to be common in newer pliocene deposits. I have not met with it.

Loc., *living.* The British Seas, and the seas of Southern Europe.

62. *Cardium echinatum*, Linnæus.

Loc., *fossil.* Scotish and Irish glacial beds. Isle of Man. [Sicily.]

Loc., *living.* General in the seas of Europe.

63. *Cardium lævigatum*, Linnæus.

Loc., *fossil.* Scotland. Isle of Man, Ireland. [Found in the newer pliocene of Sicily.]

Loc., *living.* General throughout the European Seas.

64. *Pectunculus pilosus* (*Arca* sp.), Linnæus.

Syn., *Pectunculus variabilis.* Sowerby (M. C.)

Loc., *fossil.* Isle of Man and Ireland. Mammaliferous crag at Thorpe.

Loc., *living.* General in the European Seas.

65. *Nucula nucleus* (*Arca* sp.), Linnæus.

Syn., *Nucula margaritacea*, Lamarck.

Loc., *fossil.* In most of the British glacial beds, but not common.

Loc., *living.* Throughout the European Seas. Does not range to Greenland.

Note. It occurs in both coralline and red crags.

66. *Nucula proxima*, Gould?

Loc., *fossil.* Among the drift fossils collected by Captain James, in Wexford, is a *Nucula*, which comes nearer to the above species of Gould, as figured in the 'Invertebrata of Massachusetts' (fig. 63), than to any species with which I am acquainted. The *Nucula nitida* of Sowerby may, as suggested by Dr. Gould, be the same species; but, if I am right as to the form usually so called, it is only a variety of *N. nucleus.*

Loc., *recent.* Seas of Massachusetts. If a deep-sea British form, taken by Mr. W. Thompson in the North of Ireland, and by Mr. MacAndrew on the West of Scotland, be identical, this will add another to the list of species common to Europe and America.

67. *Nucula tenuis.* (*Arca* sp.), Montagu.

Syn., *Nucula tenera*, S. Wood.

Loc., *fossil.* In the Clyde beds, and in Ireland. In the mammaliferous crag of South Wold.

Loc., *living.* In the British (chiefly North) Scandinavian and Arctic Seas. Seas of Greenland and Boreal America.

Note. Appears in the red crag.

68. *Nucula Cobboldiæ*, Sowerby (M. C.).

Loc., *fossil.* In the mammaliferous crag of Bramerton. Bridlington. A fragment found by Captain James in the Wexford beds probably belongs to this species. It is not now known living. It appeared within our area during the Red Crag epoch, and was probably extinguished by the upheaval of the limited area through which it ranged. It is the finest species of its genus.

Leda. This genus was established by Schumacher for the reception of the beaked *Nuculæ*. It has been lately revived, and more precisely defined by P. C. Möller, in his 'Index Molluscorum Groenlandiæ.' In that treatise the author groups the forms of *Nuculæ* inhabiting Greenland under three genera, *Leda*, *Nucula*, and *Yoldia.* Of the first, the *Nucula minuta* is an example; of the second, *Nucula nucleus*; and of the third, *Nucula arctica.* The shell of the first is beaked, and very inæquilateral; of the second, longitudinally ovate, oblique, and inæquilateral; and of the third, transversely oblong, and usually nearly æquilateral. The essential characters of the animals are enumerated as follows:—

Leda. "Animal tubis, brevibus, tenuibus, rectis præditum; pede longo, tenui, flexili; pallio toto aperto, marginibus simplicibus."

Nucula. "Animal sine tubis exsertilibus, pede brevi, crasso; pallii parte solum inferiore aperta."

Yoldia. "Animal tubis longis curvatis instructum; pede magno, valido; pallio toto aperto, marginibus posticè ciliatis."

I have never seen the animal of a *Yoldia;* but, having compared those of *Nucula* and *Leda*, and the latter with the description given by Möller of *Yoldia*, I am inclined to restrict the division of the genus *Nucula* into two generic groups instead of three, and to unite *Yoldia* with *Leda*, under the latter name. The animal of *Leda minuta*, as will be seen by the following sketch,

has two siphonal tubes, which are long, and may be curved. The margin of the mantle also is crenate.

The animal of *Leda pygmæa*, which Möller mistook for a true *Nucula*, and described under the name of *Nucula lenticula*, is intermediate in character between his *Leda* and *Yoldia*, as will be seen from the accompanying figure, drawn from a living Scottish specimen.

In both forms we see exsertile siphons, which are wanting in the true *Nuculæ*; as in *Nucula tenuis*.

This important distinction shows that the division of the lamellibranchiated *Acephala* into two groups, according to the presence or absence of prolonged siphons (corresponding to the integrity or sinuation of the pallial impression in the shell), is artificial. In the *Nuculidæ* it is evident that the dental characters of the hinge are of more importance. The genus *Solenella*, which M. A. D'Orbigny has separated from the *Nuculidæ*, on account of its sinuated pallial impressions, and placed among the *Anatinæ*, may therefore be restored to its former and natural position.

69. *Leda minuta* (*Arca* sp.), Otho Fabricius.

Syn., *Nucula rostrata*, Sowerby. *Nucula tenuisulcata*, Couthouy (*fide* Gould).

Loc., *fossil*. In most of the British glacial beds, but not so common as the next. (Russia ?).

Loc., *living*. British, Scandinavian, and Arctic Seas. Greenland and Boreal America.

Note. In the red crag of Sutton.

70. *Leda rostrata* (*Nucula* sp.), Lamarck.

Syn., *Nucula oblonga*, Brown.

Loc., *fossil.* One of the most characteristic shells of the glacial beds, and very generally distributed. [Sweden, Russia.]

Loc., *living.* In the Arctic Seas.

71. *Leda pygmæa* (*Nucula* sp.), Goldfuss.

Syn., *Nucula gibbosa*, Smith. *Nucula tenuis*, Phillippi. *Nucula lenticula*, Möller.

Loc., *fossil.* In the Clyde beds, evidently *in situ.* [In the newer pliocene of Sicily.]

Loc., *living.* Seas of Greenland. Known only in one spot in the British Seas, viz., the Sound of Skye.

Note. Appeared in our seas during the Coralline Crag epoch, between which time and the Glacial epoch it must have been very generally distributed through the European area.

72. *Leda* (*Yoldia*) *oblongoides*, Wood.

Syn., *Yoldia angularis*, Möller. Variety of *Nucula myalis*, Couthouy? *Nucula hyperborea*, Löven? Bramerton.

Loc., *fossil.* Found by Captain James in the Wexford beds. [Sweden, Canada.]

Loc., *living.* In the Arctic Seas.

Note. In the red crag (*oblongoides*); according to Mr. Searles Wood.

73. *Leda.* sp. nov.?

The fragment of a species resembling in form the *Nucula pusio* of Phillippi, ('Enumeratio Moll. Sic.,' vol. ii. to xv. J. S.), but having a smooth exterior, has been found by Captain James in the drift beds of Wexford, where we may expect more perfect specimens of both this and the last.

74. *Mytilus edulis*, Linnæus.

Syn., *M. alæformis*, Sowerby (M. C.), *antiquorum*, Woodward.

Loc., *fossil.* In most of the glacial beds of Britain. Mammaliferous crag at Norwich. [Scandinavia, Russia, Canada.]

Loc., *living.* Seas of Northern and Celtic Europe; Greenland; coasts of Boreal America. [*M. borealis*, De Kay.]

Note. Fossil in the red crag.

75. *Mytilus* (*Modiolus*) *vulgaris.* Fleming.

Syn. *Modiola modiolus* and *Mytilus modiolus* of many authors, but (according to Mr. Hanley) not the *Mytilus modiolus* of Linnæus. *M. papuanus* of Lamarck?

Loc., *fossil.* Scottish and Irish beds. Mammaliferous crag of Portwick.

Loc., *living.* British and Scandinavian Seas. Coasts of Boreal America.

76. *Pecten islandicus* (*Ostrea* sp.), Muller.

Syn., *Ostrea cinnabarina*, Born. *Pecten Pealii*, Conrad (*fide* Gould).

Loc., *fossil.* Clyde beds, where it occurs with the valves united and evidently *in situ.* [Russia, Sweden, Canada.]

Loc., *living.* Seas of Greenland, Iceland, and Boreal America.

77. *Pecten maximus* (*Ostrea* sp.), Linnæus.

Loc., *fossil*. Ireland, rare.

Loc., *living*. Celtic and Scandinavian Seas.

78. *Pecten opercularis* (*Ostrea* sp.), Linnæus.

Syn., *P. plebeius* and *sulcatus* of the Mineral Conchology.

Loc., *fosssil*. Clyde beds. Mammaliferous crag of Southwold.

Loc., *living*. Throughout the European Seas.

Note. Is found fossil in both coralline and red crags.

79. *Pecten varius* (*Ostrea* sp.), Linnæus.

Loc., *fossil*. Scotland? Wexford, but very rare. [Sweden.]

Loc.. *living*. Throughout the European Seas.

80. *Pecten sinuosus* (*Ostrea* sp.), Linnæus.

Syn., *Pecten striatus* of the Mineral Conchology (fossil in the red and coralline crags) can scarcely be distinguished from this species. *Pecten distortus*, Montagu. *Pecten pusio*, Pennant. The young shell is the *Pecten pusio* of Turton, and *Pecten spinosus* of Brown. It can scarcely be distinguished from the adult Mediterranean *pusio*.

Loc., *fossil*. Ireland. The Clyde.

Loc., *living*. Celtic and Scandinavian Seas.

81. *Pecten triradiatus*, Muller.

Syn., *P. obsoletus* of British authors.

Loc., *fossil*. In the mammaliferous crag of Bramerton. Loch Lomond beds.

Loc., *living*. Celtic and Scandinavian Seas.

Note. Occurs in the red crag.

82. *Ostrea edulis*. Linnæus.

Loc., *fossil*. Frequent in the drift of Scotland and Ireland.

Loc., *living*. Seas of Celtic and Northern Europe. Coast of the United States (if identical with *Ostrea borealis*). Dr. Gould says, "The oystermen maintain that our shell is identical with the English *O. edulis;* and there are certainly forms in which the American and European specimens could not be distinguished."—*Invertebrata of Massachusetts*, p. 138.

Note. In the coralline crag. Nyst enumerates it among the Campinian fossils of Belgium.

83. *Anomia ephippium*, Linnæus.

Loc., *fossil*. English and Irish drift, and Sweden.

Loc., *living*. Throughout the seas of Europe. Coasts of the United States and Canada.

84. *Anomia squamula*, Linnæus.

Syn., (var.) *Anomia aculeata*, Gmelin.

Loc., *fossil*. Irish drift. Bridlington.

Loc., *living*. Throughout the European Seas, and on the coast of Boreal America.

Gasteropoda.

85. *Dentalium entalis*, Linnæus.

Loc., *fossil*. Isle of Man. North of England. Wales. Ireland. Bridlington.

Loc., *living*. General in the European Seas.

Note. "*Dentalium dentalis*" has been recorded as a pleistocene shell from Bamff, and "*Dentalium striatum*" from Preston. By the former *Dentalis* is probably meant. What the Preston shell was it is difficult to say without an examination of the specimens.

86. *Patella vulgata*, Linnæus.

Loc., *fossil*. Usually in the sandy and gravelly beds of the British pleistocene. [Sweden.]

Loc., *living*. In the Northern and Celtic regions of the European Seas.

Note. Appears in the reg crag. It is enumerated by Phillippi with a mark of doubt as an inhabitant of the Sicilian Seas during the Newer Pliocene epoch.

87. *Patella pellucida*, Linnæus.

Loc., *fossil*. Clyde beds, Dalmuir.

Loc., *living*. Celtic and northern regions of the European Seas. Constantly in the Laminarian zone.

88. *Patella lævis*, Pennant.

Syn., *Patella cœrulea*, Montagu.

Loc., *fossil*. Ireland. Bamff.

Loc., *living*. Celtic and northern regions of the European Seas, with the last. The distribution of this species and of *Patella pellucida* depends probably on that of the *Laminariæ*, on the leaves or in the root of which *fucus* they live. Their presence in an upheaved bed is an excellent indication of the depth at which it was formed.

[89. *Lottia testudinalis* (*Patella* sp.), O. F. Muller.

Syn., *Patella tessellata*, Muller. Z. D. *Patella Clealandi*, Sowerby. *Patella clypeus*, Brown. *Patella amœna*, Say.

Loc., *fossil*. Sweden.

Loc., *living*. The seas of Northern and Arctic Europe. Greenland and Boreal America.]

90. *Lottia virginea*, Muller.

Syn., *Patella parva*, Da Costa. var. *Patella æqualis* (Sowerby in Min. Conch.).

Loc., *fossil*. Scottish beds, frequent. Ireland, rare. [Sweden.]

Loc., *living*. Celtic and northern regions of the European Seas.

Note. In the coralline and red crags. [Is *Lottia parvula* this species?]

91. *Fissurella græca* (*Patella* sp.), Linnæus.

Syn., *Fissurella reticulata*, Donovan. *Fissurella cancellata*, Wood.

Loc., *fossil*. Clyde beds. [Sweden.]

Loc., *living*. Throughout the European Seas.

Note. In both red and coralline crags.

92. *Cemoria noachina* (*Patella* sp.), Chemnitz.

Syn., *Patella fissurella*, Muller. *Cemoria Flemingii*, Leach. *Puncturella noachina*, Lowe. *Sipho striata*, Brown.

Loc., *fossil*. Clyde and other beds in Scotland. [Sweden, Norway.]

Loc., *living*. Seas of Northern and Arctic Europe, Greenland, and Boreal America.

93. [*Emarginula crassa*, Sowerby (M. C.)

Loc., *fossil*. Norway.

Loc., *living*. Scandinavian and Scottish Seas.]

94. [*Capulus hungaricus* (*Patella* sp.), Linnæus.

Hisinger enumerates this species found living in all the European Seas, among the drift fossils of Sweden.]

95. *Velutina lævigata* (*Helix* sp.), Linnæus.

Syn., *Helix haliotoidea*, Otho Fabricius. *Bulla velutina*, Muller. *Velutina capuloidea*, Blainville. *Velutina rupicola*, Conrad.

Loc., *fossil*. Drift beds of Scotland and Ireland. Mammaliferous crag of Bramerton.

Loc., *living*. Seas of Celtic, Northern and Arctic Europe, Greenland and Boreal America.

Note. Occurs in the red crag.

96. *Velutina elongata*, Forbes and Goodsir.

Syn., *Velutina lanigera*, Möller ?

Loc., *fossil*. Mammaliferous crag of Thorpe, according to Mr. Searles Wood.

Loc., *living*. Scottish Seas, very rare.

97. *Velutina undata*, Smith.

Syn., *Velutina zonata*, Gould.

Loc., *fossil*. Seas of Boreal America.

Loc., *living*. Clyde beds. [Canada.]

98. *Lacuna Montacuti*, Turton.

Syn., *Helix lacuna*, Montagu. *Lacuna neritoidea*, Gould ?

Loc., *fossil*. Ireland.

Loc., *living*. Seas of Celtic and Northern Europe. Coast of Massachusetts.

99. *Lacuna vincta* (*Helix* sp.), Montagu, and β. *Canalis*, Turton. *Lacuna pertusa*, Gerrard.

Loc., *fossil*, Dalmuir, Bute.

Loc., *living*. Celtic and Northern Seas. Seas of Boreal America. The distribution of the *Lacunæ* is coextensive with that of the *Laminariæ*.

100. *Littorina littorea* (*Turbo* sp.), Linnæus.

Loc., *fossil*. In the glacial beds of England and Ireland. Mammaliferous crag of Bramerton. Bridlington. [Sweden, Russia.]

Loc., *living*. Celtic and Northern regions of the European Seas.

Note. Numerous varieties, which have received as many names in Woodward's 'Geology of Norfolk,' occur in the red crag.

101. *Littorina rudis* (*Turbo* sp.), Maton.

Syn. (var). *Turbo jugosus*, Maton. *Turbo obligatus*, Say. β. *Littorina tenebrosa* (*Turbo* sp.), Maton.

Loc., *fossil*. Scottish, English, and Irish beds [Sweden].

Loc., *living*. Celtic, Northern and Arctic regions of the European Seas Coasts of Boreal America.

102. *Littorina palliata*, Say.

Syn., *Turbo expansus*, Brown and Smith. *Littorina arctica*, Möller.

Loc., *fossil*. Clyde beds. [Canada.]

Loc., *living*. Arctic Seas, and coasts of Boreal America.

103. *Rissoa semicostata* (*Turbo* sp.), Montagu.

Loc., *fossil*. Mammaliferous crag of Bramerton.

Loc., *living*. Celtic Seas.

Note. The species is found in the red crag.

104. *Rissoa sub-umbilicata* (*Turbo* sp.), Montagu.

Syn., *Turbo minutus*, Woodward.

Loc., *fossil*. In the mammaliferous crag of Bramerton.

Loc., *living*. Celtic Seas.

105. *Scalaria groenlandica* (*Turbo* sp.), Chemnitz.

Var. β. *similis*, Sowerby (M. C.). *Scalaria subulata*, Couthouy.

Loc., *fossil*. Mammaliferous crag of Thorpe; Bridlington, Ireland? [Sweden, Canada].

Loc., *living*. Seas of Greenland and Boreal America.

106. [*Scalaria borealis*.

Loc., *fossil*. Canada, Sweden.

Loc., *living*. Arctic Seas.]

107. *Turritella terebra* (*Turbo* sp.), Linnæus.

Syn., *Turritella communis*, Risso. *Turritella Linnæi*, Deshayes.

Loc., *fossil*. General in the pleistocene beds of Britain. Mammaliferous crag of Bramerton, Bridlington.

Loc., *living*. Generally distributed through the European Seas.

Note. Occurs in both coralline and red crags.

108. *Turritella incrassata*, Sowerby (M. C.).

Syn., *Turritella triplicata*, Brocchi.

Loc., *fossil*. In the glacial beds of Wexford, not rare.

Loc., *living*. In the Lusitanian and Mediteranean Seas.

Note. This species appeared in our area during the Coralline Crag epoch. It occurs in the red crag. In the drift it is only found towards its southernmost limits. At the close of the Glacial epoch, it retired to more southern seas, and is now abundant on the coast of the south of Spain. Both fossil and recent specimens vary extremely, the whorls presenting every degree of convexity, and in some examples being quite flat. The number and form of the spiral ridges vary, but in every case the interstices are finely striated.

109. *Cerithium punctatum*, Woodward.

Loc., *fossil*, Bramerton.

Note. Not known living. A red crag species.

110. *Aporrhais pes-pelecani* (*Strombus* sp.), Linnæus.

Loc., *fossil*, Dalmuir. Ireland.

Loc., *living*. Throughout the Northern Celtic, Lusitanian, and Mediterranean provinces of the European Seas.

Note. Appears in British area during the Coralline Crag epoch. Is found in the red crag.

111. *Murex erinaceus*. Linnæus.

Loc., *fossil*. Scottish and Irish beds. Mammaliferous crag, near Norwich.

Loc., *living*. Throughout the seas of Western Europe. The Mediterranean.

112. *Fusus muricatus* (*Murex* sp.), Montagu.

Syn., *Fusus echinatus*, Phillippi (an Sowerby ?). *Fusus variabilis*, De Cristoforis and Jan (*fide* Phillippi).

Loc., *fossil*. County of Wexford.

Loc., *living*. Throughout the European Seas. Seas of Boreal America.

113. *Fusus Barvicensis*, Johnston.

Loc., *fossil*. Irish drift.

Loc., *living*. Northern coasts of Britain.

114. *Fusus Bamffius* (*Murex* sp.), Donovan.

Loc., *fossil*. One of the most generally diffused and abundant species in the British and Irish glacial beds.

Loc., *living*. Northern and Arctic regions of the European Seas. Common on the Scottish coasts. Greenland. Seas of Boreal America.

115. *Fusus scalariformis*, Gould.

Syn., *Fusus Peruvianus*, Lamarck. *Fusus lamellosus*, Sowerby. *Fusus costatus*, Hisinger.

Var. β. *Fusus imbricatus*, Smith.

Loc., *fossil*. In the Scotch and Irish glacial beds, of which with the last it is a very characteristic fossil. Bridlington. [Sweden, Russia.]

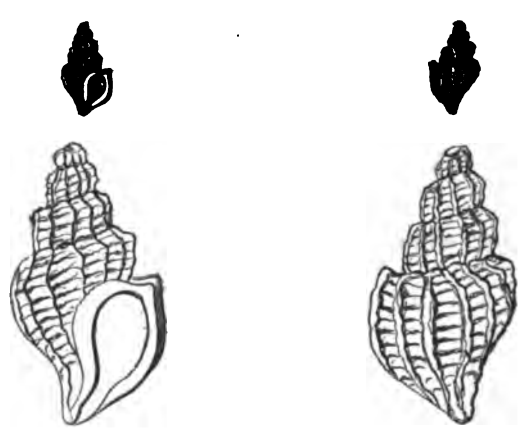
Loc., *living*. In the Arctic Seas. Greenland. Seas of Boreal America.

Note. A red crag fossil.

116. Fusus *Fabricii*, Beck (*fide* Möller).

Syn., *Murex craticulus*, Otho Fabricius.

This beautiful species, which was not observed in the drift beds until found in Ireland by Captain James, is intermediate in its character between *Fusus scalariformis* and *Fusus Barvicensis*. It has the general form and ventri-



cose whorls of the former, with the fimbriated ribs of the latter. In the above cut, from a drawing by Mr. W. Bailey, specimens of natural size are represented by the two uppermost figures, and magnified views by the two lower.

Loc., *fossil*. Drift beds of Wexford.

Loc., *living*. Seas of Greenland.

117. *Fusus*, nov. sp. ? or variety of *F. crispus*, Brocchi.

A shell measuring above an inch in length, fusiform, the whorls narrow, and crossed by prominent ribs which are traversed by raised spiral ridges. The characters are those of *Fusus crispus*, of which it is probably an extreme form; but more perfect specimens are required for accurate determination. It is very distinct from any recorded drift fossil.

Loc., *fossil*. Wexford.

Loc., *living*. *Fusus crispus* is at present a Mediterranean species. It occurs fossil in the sub-Appennine beds.

118. *Fusus Forbesi*, Strickland. [According to Mr. G. Sowerby, identical with *Fusus cinereus* of Say, an American species synonymous with the *Buccinum plicosum* of Menke.]

Loc., *fossil*. Isle of Man.

Loc., *living*. Coasts of United States.

119. *Fusus Sabini*. Gray.

Syn., (var.) *Fusus ventricosus*, Gray?

Loc., *fossil*. Irish drift. Bridlington.

Loc., *living*. Banks of Newfoundland. Arctic Seas. Zetland. Closely resembles the following species.

120. *Fusus Islandicus*, Martini.

Syn., *Fusus corneus* of British authors, but not of Linnæus. *Fusus angustus*, S. Wood.

Loc., *fossil*. Irish drift.

Loc., *living*. Common in the Celtic, Northern, and Arctic Seas. Greenland. Coasts of Boreal America.

121. *Fusus despectus*, (*Murex* sp.), Linnæus.

Syn., *Fusus carinatus*, Lamarck.

Fusus striatus, var. *carinatus*, Sowerby (M.C.).

Fusus tornatus, Gould. *Tritonium fornicatum*, Fabricius.

Loc., *fossil*. In the mammaliferous crag of Bramerton. Dalmuir. Bridlington: a specimen from the last locality in Mr. Bowerbank's collection is reversed, and frequently ribbed like the *Fusus decemcostatus* of Say. [Russia, Canada.]

Loc., *living*. Very rare in the British Seas. Arctic Seas. Greenland. Seas of Boreal America.

122. *Fusus antiquus*. (*Tritonium* sp.), Muller.

Syn., *Murex despectus*, Montagu.

(Reversed variety.) *Fusus contrarius*. (*Murex* sp.), Sowerby (in M.C.).

Loc., *fossil*. Both forms are found in the Irish drift, but chiefly (in the south) the reversed variety. The normal form occurs in the Scotch beds. Mammaliferous crag of Bramerton.

[In the Sicilian newer pliocene beds, the reversed variety is found, though both forms are now extinct in the Mediterranean regions.]

Loc., *living*. Celtic, Northern, (and Arctic?) Seas of Europe; rarely reversed.

Note. The reversed variety is found in the Campinian beds of Belgium.

123. *Pleurotoma turricula.* (*Murex* sp.), Montagu.

SYN., *Murex angulatus*, Donovan. *Pleurotoma Woodiana*, Möller.

LOC., *fossil.* A very variable species, common in the Scotch and Irish beds. Also in the north of England and Isle of Man. In the Bridlington beds, where there are several curious varieties, possibly identical with some of the supposed species into which Möller ('Index Molluscorum Groenlandiæ') has divided this *Pleurotoma.* In the mammaliferous crag of Bramerton.

LOC., *living.* Celtic, Northern, and Arctic provinces of the European Seas. Greenland and Boreal America.

Note. It occurs in the red crag.

124. *Pleurotoma discrepans*, Brown.

SYN., *Pleurotoma decussata,* Couthouy ?

LOC., *fossil.* Dalmuir.

LOC., *living.* Scottish Seas, very rare. Seas of Boreal America (if *decussata*).

125. *Pleurotoma septangularis* (*Murex* sp.), Montagu.

LOC., *fossil.* Ireland.

LOC., *living.* British Seas.

126. *Pleurotoma rufa* (*Murex* sp.), Montagu.

LOC., *fossil.* Ireland. Mammaliferous crag of Thorpe.

LOC., *living.* British Seas. Seas of Boreal America.

127. *Pleurotoma* sp.

LOC., *fossil.* A small, tapering, smooth species, from Wexford, closely resembling a form now living among the Channel Isles, but too imperfect for determination.

128. *Pleurotoma* sp.

A small species nearly allied to *Pleurotoma linearis.* The whorls are convex, spirally furrowed, and strongly ribbed longitudinally. The ribs on the body whorl are twelve. More perfect specimens are required. From Wexford.

129. *Buccinum undatum*, Linnæus ; and var. β. *tenerum* (M. C.).

LOC., *fossil.* Common in the glacial beds of Britain and Ireland, varying from the strong and coarsely-ribbed normal form to thin and slightly-undulated varieties, which can scarcely be distinguished from the next species. *Buccinum striatum* of Smith appears to be one of these varieties. Bridlington.

[Sweden, Russia. During the same epoch it inhabited the Mediterranean, but no longer lives there now.]

LOC., *living.* Celtic, Northern and Arctic regions of the European Seas. Coasts of Boreal America, from Cape Cod northwards.

Note. It appeared within our area during the Coralline Crag epoch.

130. *Buccinum ciliatum.* Fabricius.

SYN. [A variety] *Buccinum Humphreysianum*, Bennett. Possibly *Buccinum fusiforme* of Broderip, may be an extreme form of this species.

LOC., *fossil.* North of England and Scotland.

Loc., *living*. Very rare in the British Seas. Common in Arctic Seas and on the banks of Newfoundland.

131. *Purpura lapillus* (*Buccinum* sp.), Linnæus.

Loc., *fossil*. Abundant in the sandy (upper) beds of the Irish drift. Common also in England and Scotland. Mammaliferous crag of Bramerton.

Loc. Living in the Celtic, Northern, and Arctic regions of the European Seas. (Replaced in the Lusitanian provinces by *Purpura hæmastoma*). Greenland; E. coast of America from Florida to the Arctic Seas.

Note. This is one of the most variable of univalve testacea. Well may Dr. Gould remark, that scarcely two specimens can be found alike. I fully agree, after examining long suites of specimens, with Mr. Searles Wood in referring *Buccinum crispatum* of the Mineral Conchology, and the *Murex angulatus*, *M. lapilliformis*, and *M. compressus*, of Woodward, to this species; nor does the *Purpura incrassata* of Sowerby appear to be more than a variety. It is probable that the *Purpura lapillus* is of American origin, and that it was introduced to the European shores during the course of events which brought about the peculiarities of the Pleistocene epoch.

132. *Nassa monensis*, Forbes.

Loc., *fossil*. In the pleistocene beds of the north of the Isle of Man. Described by Mr. Strickland in the fourth volume of the 'Proceedings of the Geological Society.' Not known as a living species.

133. *Nassa pliocena*, Strickland.

Loc., *fossil*. In the pleistocene beds of the north of the Isle of Man. Described by Mr. Strickland in the fourth volume of the 'Proceedings of the Geological Society.' Not known as a living species.

134. *Nassa reticulata*, Linnæus.

Loc., *fossil*. In the Scotch, Manx, Lancashire, and Irish beds.

Loc., *living*. Throughout the Northern, Celtic, and Lusitanian regions of the European Seas.

135. *Nassa semistriata*, Brocchi.

Syn., *Buccinum labiosum*, Sowerby.

Loc. In the Wexford beds.

Loc., *living*. In the depths of the Ægean.

Note. This is a very abundant tertiary fossil in the miocene beds of Touraine, &c. It is found in the coralline and red crag, and occurs in the Newer Pliocene beds of Sicily and Rhodes.

136. *Nassa granulata*, Sowerby (M. C.).

Loc., *fossil*. In the mammaliferous crag of Bramerton. In Ireland, at Killiney.

Note. A red crag fossil.

137. *Nassa incrassata* (*Tritonium* sp.), Muller.

Syn., *Nassa macula* (*Buccinum* sp.), Montagu.

Loc., *fossil*. Common in all the glacial beds of Britain and Ireland.

Loc., *living*. In the Northern, Celtic, and Lusitanian regions of the European Seas, but chiefly in the two first. It ranges to Madeira.

Note. A red crag fossil.

138. *Trichotropis borealis*, Sowerby.

SYN., *Fusus carinatus, jun.* Laskey.

Fusus umbilicatus, Smith and Brown.

Trichotropis acuminatus, Jeffreys.

Trichotropis costellatus, Couthouy.

Loc., *fossil.* Ireland. Bridlington. [Canada.]

Loc., *living.* Seas of Scotland, Scandinavia, Arctic Seas, Greenland, coasts of America from Massachusets northwards.

Note. A coralline crag fossil.

139. *Cancellaria costellifer* (*Murex* sp.), Sowerby (M. C.).

SYN., *Cancellaria buccinoides*, Couthouy. *Cancellaria Couthouyi*, Jay.

Loc., *fossil.* Bridlington.

Loc., *living.* Inhabits the E. coast of America, from Massachusets to the Arctic Seas.

Note. This species appeared in our area during the Coralline Crag epoch, and continued during the formation of the red crag. It is now restricted to the other side of the Atlantic. It is essentially a Boreal form, though the genus is sub-tropical.

140. *Mitra* species: an *Mitra cornea*, Lamarck?

Loc., *fossil.* A single specimen of a *Mitra* has occurred in the glacial beds of Wexford. It is too much broken to determine the species, but having the columella entire, with the folds perfectly preserved, there can be no question respecting the genus. Its proportions, and the number, &c., of the folds on the lip approach so nearly to those of *Mitra cornea* that I have little doubt better specimens will prove the fossil to have been identical with that species. I have compared it with the *Mitra groenlandica* (specimens of which are in the British Museum) of Möller, a species which we may expect possibly to be preserved in the drift. The Greenland shell is about the same size as our fossil, but in other respects is very different. The existence of a *Mitra* in Greenland is an apparent anomaly in the distribution of the species of that genus, which would seriously militate against the idea entertained by many naturalists (and to which I am inclined to subscribe) of the existence of *generic centres.* The shell before us does away with the anomaly, for we now find in the very beds which were deposited in a sea, the fauna of which was most nearly related to that of Greenland now, a *Mitra* linking, as it were, the true seat of the genus in the southern and tropical regions, with its outpost in the far north.

Loc., *living.* *Mitra cornea* is a characteristic species of the Mediterranean and Lusitanian regions of the European Seas. It occurs fossil in the newer pliocene beds of Sicily.

141. *Tornatella pyramidata* (*Auricula* sp.), Sowerby (M. C.).

Loc., *fossil.* A well-marked, large, and entire specimen of this fine species has been found in the Wexford beds.

142. *Cypræa Europæa*, Linnæus.

Loc., *fossil.* Irish drift.

Loc., *living.* Throughout the European Seas.

[The basal portion of a *Cypræa* as large as *Cypræa moneta* has been brought to Captain James as having been found in the Wexford drift. As, however, there is something about its aspect which renders it doubtful whether it be not a fragment of a recent shell, I think it better to give merely this notice of it for the present.]

143. *Natica monilifera*, Lamarck.

Syn. *Natica glaucina* of British authors. Perhaps identical with *N. castanea* of Lamarck. *Natica glaucinoides* of Sowerby (M. C.), not of Deshayes, as pointed out by Mr. Searles Wood, who has named the crag fossil *N. catenoides*. I am induced to regard the crag and drift forms as one species, and as identical with the living British *monilifera*. The furrow round the spire is certainly owing to a process of decortication produced during decay. *N. fragilis*, Smith, appears to me to be the same much decayed.

Loc., *fossil*. In the Scotch, English, Manx, and Irish glacial beds, frequent. In the mammaliferous crag at Bramerton. [Sweden.]

Loc., *living*. In the Celtic and Northern (and Lusitanian) regions of the European Seas.

Note. In both the coralline and red crag.

144. *Natica* sp. nov.? (*Bowerbankii*, Forbes, MSS.)

In Mr. Bowerbank's Bridlington collection there is an imperfect specimen of a very distinct species of *Natica*, which does not agree with any living or fossil species known to me. It has a smooth ventricose body whorl, angulated above, and a depressed spire. It equals the *Natica monilifera* in size.

145. *Natica Alderi*, Forbes.

Syn. *Natica catena* of many British authors. *Natica anglica* of some catalogues.

Loc., *fossil*. Scottish and Irish drifts.

Loc., *living*. Northern, Celtic, and Lusitanian regions of the European Seas.

Note. A red crag fossil.

146. *Natica helicoides*, Johnston.

Loc., *fossil*. In the mammaliferous crag of Bramerton.

Loc., *living*. Seas of the north and east of Scotland.

Note. A red crag species. Much more plentiful fossil than recent.

147. *Natica clausa*, Broderip and Sowerby.

Syn., *Natica consolidata*, Couthouy.

Natica septentrionalis, Beck.

Loc., *fossil*. Scottish, Manx, Irish, and North of England glacial beds. Bridlington (Sweden, Russia, Canada).

Loc., *living*. Arctic Seas and seas of Boreal America.

Note. This fossil occurs in the red crag.

148. *Natica groenlandica*, Beck.

Loc., *fossil*, Bridlington.

Loc., *living*. Seas of Greenland. Extremely rare in the British Seas.

149. *Natica Smithii* (*Bulbus* sp.), Brown.

Loc., *fossil*. The only specimen ever met with of this most interesting

shell, a member of the division of ampullariform Naticæ, was found by the Duchess of Argyle in the pleistocene beds at Ardincaple. That specimen was presented to Mr. Smith, and was figured and described by Captain Brown in the eighth volume of the Wernerian Transactions. It has since, unfortunately, been destroyed. From its delicacy, it is not likely to occur in the more disturbed beds of the drift, but should be looked for in the Clyde beds. It is extremely probable that when an opportunity for comparison may occur, the *Bulbus Smithii* will be found to be identical with the *Natica flava* of Gould, a rare living inhabitant of the Newfoundland Bank.

[150. *Coriocella perspicuus* (*Helix* sp.), Linnæus.

SYN., *Bulla haliotoidea*, Montagu. *Sigaretus haliotoideus* of Fleming.

Loc., *fossil*. Sweden.

Loc., *living*. Seas of Europe and Boreal America.]

151. *Bulla obtusa*, Montagu.

SYN., *Bulla minuta*, Woodward.

Loc., *fossil*. Mammaliferous crag.

Loc., *living*. European Seas.

152. *Margarita undulata*, Sowerby?

SYN., *Trochus inflatus*, Smith. *Trochus tumidus*, Hisinger (not of other authors).

Loc., *fossil*. Clyde beds. [Sweden.]

Loc., *living*. Arctic Seas and seas of Boreal America. Very rare in the northern European region.

153. *Trochus ziziphinus*, Linnæus.

Loc., *fossil*. In the upper beds of the Irish drift. The variety found is very strongly ribbed spirally, and the ridges slightly nodose. The same variety now lives in Falmouth harbour.

Loc., *living*. Throughout the Northern, Celtic and Lusitanian regions of the European Seas, but chiefly developed in the two former.

Note. It occurs in the red crag.

154. *Trochus exasperatus*, Pennant.

SYN., *Trochus exiguus*, Montagu. *Trochus crenulatus*, Brocchi.

Loc., *fossil*. One of the southern species which occur in the Wexford beds.

Loc., *living*. In the southernmost parts of the British Seas, and abundant in the Lusitanian region. Phillippi enumerates it among Ehrenberg's Red Sea shells.

155. *Trochus cinerarius*, Linnæus.

Loc., *fossil*. In the Scotch, and rarely in the Irish beds.

Loc., *living*. In the northern and Celtic regions of the European Seas.

156. *Trochus tumidus*, Montagu.

Loc., *fossil*. Dalmuir.

Loc., *living*. In the northern and Celtic regions of the European Seas.

ARTICULATA.

Cirrhipeda.

1. *Balanus communis*, Pulteney.

SYN., *Lepas balanus*, Linnæus. *Balanus sulcatus*, Lamarck.

Loc., *fossil*. In the Scotch and Irish pleistocene beds, not unfrequent. [Russia, Sweden.]

Loc., *living*. In the northern and Celtic regions of the European Seas.

Note. Fossil in the coralline and red crags.

2. *Balanus balanoides* (*Lepas* sp.), Linnæus.

SYN., *Balanus vulgaris*, Da Costa. *B. ovularis*, Lamarck.

Loc., *fossil*. Fragments of this species occur in most of the British pleistocene beds. Mammaliferous crag of Postwick.

Loc., *living*. European and North American Seas.

Note. A red crag species.

3. *Balanus uddevallensis*, Linnæus.

SYN., *Balanus candidus*, Wood. *Balanus scoticus*, Wood.

Loc., *fossil*. Valves of this species are not unfrequent in the British pleistocene beds. [Sweden, Canada.]

Note. All the British glacial *Balani* I have yet seen may be referred to the three preceding species. The following, however, have been enumerated in addition, and should be carefully sought for.

Balanus costatus, Clyde.

Balanus rugosus, Clyde.

Balanus punctatus.

Balanus tintinnabulum (a mistake?)

[4. *Balanus miser*, Gould.

Loc., *fossil*. Canada, Mr. Lyell.]

5. *Creusia verruca* (*Lepas* sp.), Chemnitz.

SYN., *Lepas stromia*, Muller. *Lepas striata*, Pennant.

Loc., *fossil*. Clyde beds.

Loc., *living*. European Seas.

Annellida.

Spirorbis corrugatus, *Serpula vermicularis* and *Vermilia triquetra* are all enumerated in Mr. Smith's list, as British pleistocene fossils. The necessity of an examination of the operculum, as recently shown by Phillippi, in order to determine the genus to which a shell-bearing annelide belongs, throws doubt on the certainty of these determinations, though none in the reference of the fossils to the species usually so called. It is impossible to determine the genus of several annelides to which the shells usually called *Vermilia triquetra* belong without having the operculum before us. That operculum may yet be found, and as the most common form of the so-called *Vermilia* in the British Seas, is the *Pomatoceros tricuspis*, it will probably prove to belong to that species. If the conclusions of Phillippi be admitted the shells of annelides can have no palæontological bearings further than as affording indications of the presence of their order and class.

RADIATA.

Echinodermata.

[1. *Echinus neglectus*, Lamarck.

Loc., *fossil*. Uddevalla in Sweden. This is the *Echinus* figured by Mr.

Lyell, in the Philosophical Transactions. I have examined the specimens and identified them with the *Echinus neglectus*.

Loc., *living*. Zetland and Norwegian Seas.]

[2. *Echinus granulatus*, Say.

Loc., *fossil*. Canada.

Loc., *living*. East coast of North America.]

Zoophyta.

3. *Cellepora pumicosa*.

Loc., *fossil*. Ireland.

Loc., *living*. European Seas.

4. *Tubulipora verrucaria* (*Discopora* sp.), Fleming.

Loc., *fossil*. Largs (Rev. Mr. Landsborough).

Loc., *living*. Celtic Seas.

PLANTÆ.

1. *Nullipora polymorpha*, Ellis.

Loc., *fossil*. In most of the British pleistocene beds.

Loc., *living*. Atlantic Ocean.

SUMMARY of species of Marine Animals and Plants as yet found fossil in pleistocene beds of the glacial region (including the mammaliferous crag and the Bridlington deposit.)

Mammalia . . .	5
Pisces	1
Mollusca	155
Cirrhipeda . . .	5
Annellida . . .	3 ?
Echinodermata . .	2
Zoophyta	2
PLANTÆ	1
	174

NOTE. The mammaliferous crag fossils in this catalogue are enumerated on the authority of the lists published by Mr. Searles Wood. A great many of the Scotch localities are taken from Mr. Smith's list; the Swedish species are given on the authority of Mr. Lyell and M. Hisinger; the Russian on that of Sir Roderick Murchison; and the North American on that of Mr. Lyell.

Researches on the Influence of Magnetism and Voltaic Electricity, on Crystallization, and other Conditions of Matter. By ROBERT HUNT, Keeper of Mining Records.

A.—INFLUENCE OF MAGNETISM.

1. AN attentive examination of the peculiar characteristics of the rocks which form the crust of the earth, leads to the conclusion, that they have, during the process of consolidation, been subjected to the influences of forces which appear to act independently of the powers of cohesion.

Although the consolidation of rocks is often due to the force of aggregative attraction, sometimes assisted by the agglutinizing properties of silica, or other cementing principles, it is evident that their molecular arrangement is frequently produced by some other power; and that crystalline structure is in all cases dependent upon some disposing agent, acting often in opposition to the influence of simple cohesion.

2. Geologists have observed a remarkable uniformity in the laminations of strata, and the divisional planes of rocks have been found by them to observe some approach to a distinct order of arrangement; in many cases approximating to the direction of the present magnetic meridian.*

Such arrangements we cannot but suppose to be dependent upon some influence, universal in character and constant in action, which is exerted in giving to the particles of matter certain conditions or properties, upon which depend their order of position in the mass; in other words, these particles are impressed with the power of arranging themselves according to some law of polarity, which may, or may not, be due to electrical excitation. The singular powers exerted by electrical currents upon matter; breaking up the strong forces of chemical affinity; re-arranging the atomic elements, and giving new forms to compound bodies, naturally lead to the supposition, that this power, which is manifestly diffused through all matter, may be concerned in producing the

* "Although the direction of the present magnetic meridian in the district may be merely temporary, and the approximation of so many great divisional planes to it therefore accidental, still their great prevalence, both in the igneous rocks and sedimentary deposits, in that direction, leads us to suppose that polar forces may have considerably governed the arrangement of the component matter of the rocks they traverse, during consolidation, either from the cooling of the former, or the chemical changes which have taken place in the latter."—*Geological Report on Cornwall, Devon, &c.*, Sir *Henry De la Beche*.

phenomena to which I have referred. Some very ingenious experiments by Mr. Robert Were Fox, in which he produced the lamination of clay by long-continued voltaic action tend rather to the confirmation of this view.*

3. The theory of M. Ampère supposes the magnetic condition of the earth to be due to currents of electricity, which traverse the globe from east to west, and it has been thought by those who are inclined to attribute the phenomena of lamination and of chemical change in rocks and minerals to electricity, that those circulating currents are the great agents on which these effects depend. It would, however, appear, that in many cases the effects arise from some merely local cause; and the peculiar conditions must therefore have arisen from some agency originating within confined limits, and to a certain extent independent of the great general electric current. That electric excitation may occur within exceedingly limited areas is quite certain, for we find that no case of chemical action can arise without producing voltaic phenomena,† and that exceedingly feeble currents are capable of effecting considerable chemical changes.‡ From a consideration of these matters, the natural inference is, certainly, that the molecular and crystalline structure of the earth's strata are dependent upon some modification of electricity, but it becomes highly necessary that this hypothesis should be examined by the test of experiment.

4. With this view many of the experiments, the results of which are detailed in this memoir, were undertaken, particularly those which relate to the lamination of clay and other substances by very weak voltaic action; and those which describe the decomposition of copper ores under the influence of the same agency. Some of these are only repetitions in modified forms, of experiments made by Mr. R. W. Fox, and published several years since by that gentleman; but they have been considerably extended and tried under such conditions as appeared desirable to remove any source of error likely to affect the results. It became of the utmost importance when entering on an inquiry of this extensive character, in which the absence of intensity of force, had to be met by the introduction of the element Time, that the experiments of other investigators should be confirmed, to prevent, if possible, after having waited many months for a result, the annoying disappointments which might occur, and with this especial object, the experiments described in the

* Report of the Royal Cornwall Polytechnic Society for 1837.

† 'Annales de Chimie, 1827,' xxxv. p. 113. 'De l'Electricité dégagée dans les actions chimiques, &c., par M. Becquerel.' The Researches of De la Rive, published in the Bibliothèque universelle, 1838, xiv. 129–171, and the admirable 'Experimental Researches in Electricity' of Professor Faraday, vol. ii. p. 91, may also be consulted.

‡ 'See Annales de Chimie, 1827,' xxxiv. p. 152. 'Des Décompositions chimiques opérées avec des forces électriques à tres-petite tension,' by M. Becquerel.

second part of this paper, and which are intended to be preliminary to others, in which, as far as possible, the conditions observed in nature will be imitated, have been most carefully made. Although first in the order of date, many of these experiments having been completed in the autumn of 1845, I have thought it would be more satisfactory that they should follow the account of the effects produced by magnetism on molecular and crystalline forces, which appear to give us the key to the explanation of the other phenomena, than that they should precede it, particularly as the voltaic experiments must be regarded as merely isolated instances, which will require to be repeated under many forms, necessarily occupying a long period of time, before we shall be enabled to deduce any general conclusions from them.

5. In the Philosophical Magazine for January, 1846, I published a notice of some experiments, under the title of 'The Influence of Magnetism on Molecular Arrangement.' The results obtained since the appearance of that paper confirm in a most striking manner, those so briefly described at that time, and the experiments have now been sufficiently numerous to enable us to deduce from them some general laws of action. It may appear that many of the experiments have no direct bearing on the question under consideration, and certainly, in the present state of the inquiry, they stand as isolated phenomena, but I have no doubt that we shall, as the examination is proceeded with, find that they are related to, and explanatory of, many of the great observed facts in nature.

6. Although the inquiry has recently acquired fresh interest from the extraordinary discoveries of Faraday on new magnetic actions,* it must not be forgotten that some indications of such results as those I am about to describe, have been long since obtained, although the experiments attracted but a small share of attention, by Muschman of Christiana,† and Hanstein.‡ I would here also refer to some experiments of Ritter, analyzed by Œrsted, pointing out the difference, which I have constantly observed, existing between the influence by the north and south poles of a magnet on chemical action.§

7. As it is of the first importance that a distinct understanding of the meaning of the terms employed in science should exist, it is necessary to explain that I shall adopt those terms which have been recently intro-

* 'Experimental Researches in Electricity,' 19th, 20th, 21st Series, by Michael Faraday, Esq., D.C.L., F.R.S., &c.—*Philosophical Transactions for* 1846.

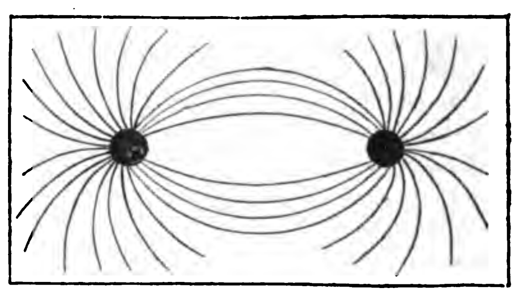
† 'Effets du Magnétisme terrestre sur la précipitation de l'Argent, observés par M. Muschman, Professeur de Chimie à l'Université de Christiana.'—*Annales de Chimie et de Physique*, 1828, vol. xxxviii. p. 201.

‡ 'Répétition et Confirmation des mêmes Expériences, par le Professeur Hansteen.'—*Ib.*, vol. xxxviii. p. 206.

§ 'Expériences de Ritter, analysées par M. Œrsted.'—*Ib.*, vol. xxxviii. p. 197. See also 'Influence du Magnétisme sur les actions chimiques,' by L'Abbé Rendu, p. 196.

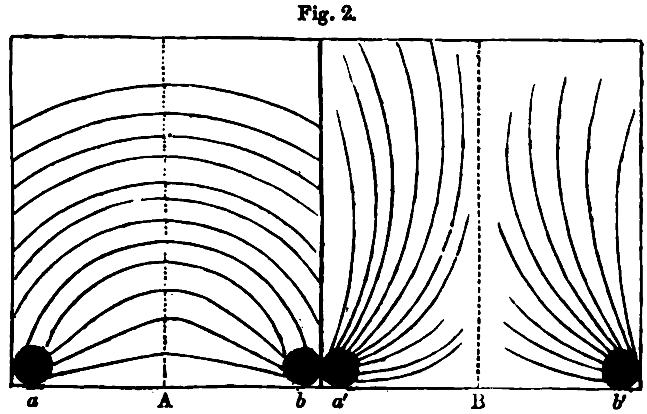
duced by Professor Faraday, whose results are strikingly confirmed by those which I have obtained by a mode of experimenting totally different, from that adopted by that talented philosopher. A *magnetic curve* means, "that exercise of magnetic force which is exerted in the lines usually called magnetic curves, and which equally exist as passing from or to magnetic poles, or forming concentric circles round an electric current." A *diamagnetic curve* means a curve formed by a body (*dia-magnetic*) "through which lines of magnetic force are passing," and which do not in any way accord with the ordinary curves produced by sprinkling of iron filings over or around the poles of a magnet. Thus the curves represented in Fig. 1 are true magnetic curves, such as are given by iron filings, shewing the circulation of lines of force between and towards either pole.

Fig. 1.



With the hope of rendering intelligible the difference between the magnetic and the dia-magnetic curves Fig. 2 is given, in which the two orders of curves are shewn, *a* and *b*, in A, representing the magnetic curve lines of connecting circulation ; *a′* and *b′*, in B, shewing the tendency of other than magnetic bodies to arrange themselves at right angles to the ordinary lines of magnetic direction.

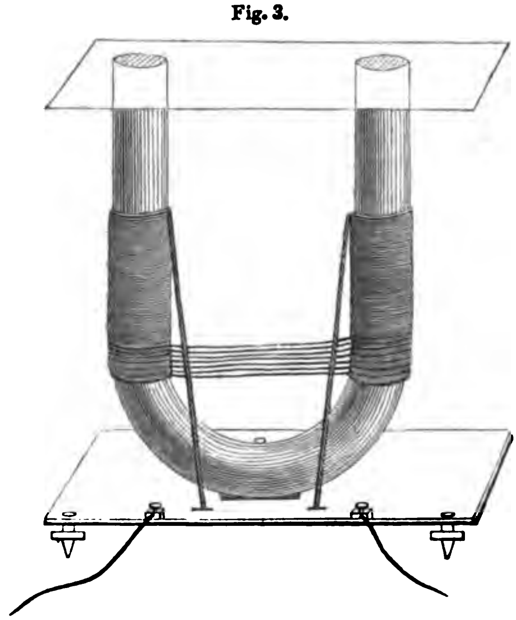
Fig. 2.



It will also be evident, from studying these two systems of arrangement, that in the one case every particle disposing itself near the north pole has a tendency to attract those which are influenced by the south pole; whereas the *diamagnetic* particles adjusting themselves under the influence of north polar force, and those which are controled by the power of the other pole, have mutually a tendency to repel each other.

8. The object in view being to ascertain the influence of magnetic force in directing the order of molecular arrangement, it was necessary to use magnets of considerable power, and so to dispose them, and the other parts of the apparatus, that the body under experiment should be free to arrange itself in any manner obediently to the polar currents, which should have full power to act, from both poles, on the particles of matter, whilst they are held in suspension between molecular and magnetic forces. It was found most convenient to use a horse-shoe-shaped electro-magnet, so arranged that glass or metal plates could be placed *upon* the poles. Fig. 3 exhibits the form of my apparatus.

Fig. 3.



It consists of a bar of soft iron, two inches in diameter and fifteen inches long, bent into a U form; around which seven coils of copper wire are wound. For the purpose of removing the body under examination as far as possible from the influence of the current which circulates through the wires, when they are connected with the voltaic battery, round pieces of iron, of the same diameter as the iron of the

magnet, ground to fit accurately upon each other, and on its poles, were provided. These being of different lengths, I was enabled to lengthen each arm of the magnet from two to six inches. This being firmly fixed on a mahogany stand, furnished with levelling screws, as shewn in the figure, enabled me to place on the poles a plate of glass or metal, edged with wax or clay, capable of holding several fluid ounces of any solution.

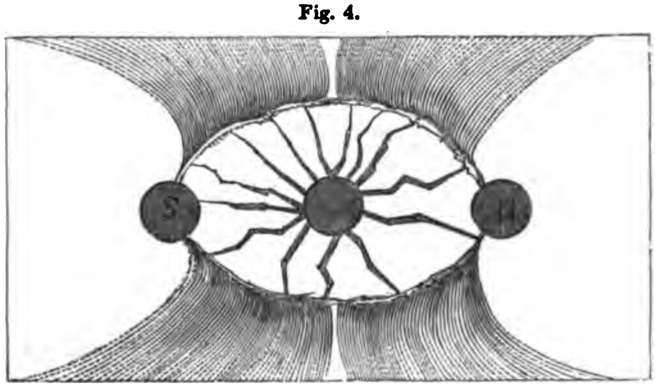
9. It being absolutely necessary that everything like a current should be prevented, the slightest motion towards any particular point distorting the delicate curve lines as they are forming, and consequently disturbing the whole result, the levelling-screw and a spirit-level are required to adjust the plate in a truly horizontal position; such is the form of apparatus employed in the experiments I have made, and the precautions necessary to be observed in conducting them.

10. A solution of nitrate of silver being placed on a glass plate on the magnet, a piece of copper wire, bent into a U was suspended so that its ends, dipping into the silver solution, were exactly over the centre of the poles. The electro-magnet being connected with a constant battery of Daniell's principle, the whole was left at rest for sixteen hours. By the action of the copper, metallic silver was slowly precipitated, copper becoming dissolved proportionally to the quantity of silver which was deposited. The silver arranged itself in a series of concentric circles around the wire, each circle being made up of very minute crystals, and divided from each other by fine bands of the oxide of silver. This arrangement was much more strikingly exhibited around the north than about the south pole; the silver formed round the latter being in much finer particles, and accumulated in mass, whereas the crystals disposed on the former, although consolidated, were found to radiate in all directions towards the circumference of the iron of the magnet. Thus were produced around the copper wire two nuclei which formed the centres, from which started off a more dispersed system of crystals. The consolidated group of crystals formed around the north pole, weighed 8·4 grains; whilst that from the south pole weighed but 6.6 grains. The crystallization which went on beyond the circle corresponding with the iron of the magnet was arranged around the north pole, in a series of the most beautiful diamagnetic curves, those springing off from the south pole being of precisely the same order but more dispersed and irregular.

11. Around the south pole, a deposit of a green colour had taken place. This may have been either an oxide of copper, or a sub-salt of that metal (the quantity was so small and so much mixed up with the silver that its exact character could not be determined). It is, however, curious to observe something like a determination of chemical action to a definite pole. This experiment has been several times repeated, and always with the same result.

12. A solution of nitrate of silver being put on the glass plate, a globule of mercury was placed, equidistant between either pole. As soon as the crystals of silver (*Arbor Dianæ*) began to form, they radiated equally from all parts of the globule, most of them crossing the *magnetic lines of force*, although many of them approached the axial line; these did not, however, extend beyond the interior edges of the magnetic poles, and in some experiments there was evidently a tendency to bend off at right angles to the line passing through the two poles at a short distance from either. The drawing (Fig. 4) represents the more

Fig. 4.

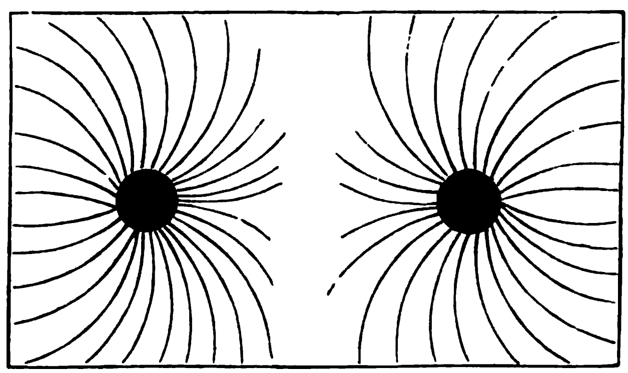


constant result. The interior system of metallic crystals having been formed, lines, which might at first be mistaken for true magnetic curves of crystals of a sub-nitrate of mercury, began to spread. Although two curved lines of crystals, extending from one pole to the other, gradually settled, yet it was found on close examination that these consisted of a great number of minute curves formed simultaneously around the centre of influence, but all of them tending to diverge from the line passing equatorially across the mercury, or the line of equilibrium between the two poles; and, assuming that order of arrangement, which, after Dr. Faraday, we call diamagnetic. Although a slight formation of crystals marked on the glass the circumferenee of the iron of the magnet, not a single crystal was found upon any part over the poles.

13. By placing equal weights of mercury *upon* the poles, the plate being filled with a solution of nitrate of silver, we get more distinct evidence of the diamagnetic arrangement. A globule of mercury being carefully placed in the centre of the space corresponding to the magnetic poles, it exhibits a tendency to move off in a curve of the repulsive order; but by moistening the plate with a little of the silver solution, the globule is rendered stationary. If the plate be now filled up with the solution of silver, there commences, almost immediately, the formation of crystals of metallic silver. These, under ordinary circumstances,

would radiate from their centres in straight lines, but now being formed within the influence of the magnetic force, and having a tendency to arrange themselves at right angles to the direction of that force, they are bent, as in the following figure, into true diamagnetic curves. When the quantity of mercury employed is large in proportion to the silver to be precipitated, the silver arranges itself, amalgamating with the mercury, in an arborescent form; but on examination it will be found that the same tendency to a curvilinear direction exists, as is more strikingly shown in the distinct crystalline forms.

Fig. 5.

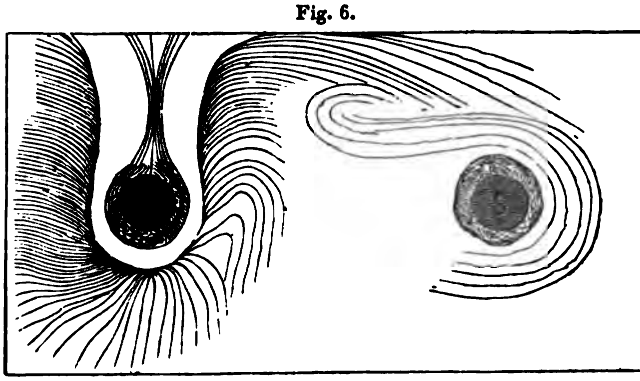


14. If we place equal weights of the proto-nitrate of mercury over the poles of the magnet, the glass plate being filled with a solution of nitrate of silver, we get very distinct evidence of a similar diamagnetic arrangement. By the action of the proto-salt of mercury on the nitrate of silver, a double sub-salt of mercury and silver results. This salt crystallizes in little tufts, and under magnetic influence these tufts arrange themselves in very symmetrical order. The salt being placed over the poles of the magnet, and the plate being filled with the solution of nitrate of silver, there is almost immediately the formation of the double sub-salt about the north pole, the first indication being very faint streaming white lines, which radiate at right angles to the line of magnetic force. These are immediately followed by circles, shown by a little clouding of the fluid, which form around the poles as in a series of waves, projected by a sort of pulsation from the magnet. The circles gradually extend, and at length opening at some point they spread off in curves as in the accompanying figure (Fig. 6.)

It will be seen on examining this figure that certain spaces, one along the axial line from the south to the north pole, and the other from the north, at right angles to it are left free of crystals; and not only that a more abundant crop of crystals occurs around the north pole, but that the power of that pole is such as to overcome, and bend back the curves

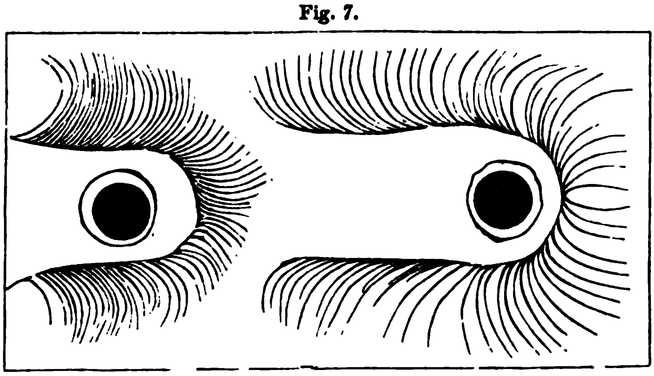
formed under the influence of the south polar force. The directions of the uncovered spaces which occurred in every experiment were at right

Fig. 6.



angles to each other. It was, however, found that this peculiar and inexplicable arrangement, was determined by a bar of iron near which the apparatus was placed by accident, and on removing it, these spaces were formed always in the same direction or along the axial line of magnetic force, as in Fig. 7.

Fig. 7.

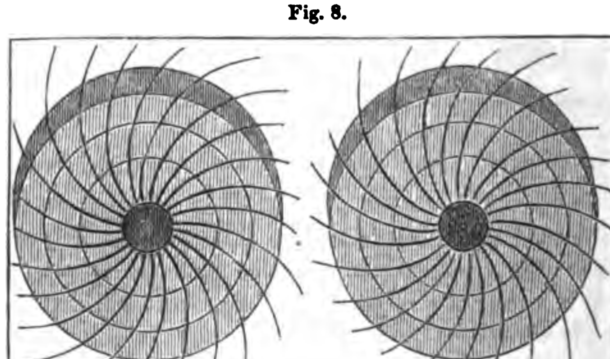


15. We must, I think, conclude from these experiments, either that the tendency of the magnetic influence or force is to repel all such bodies from it as are not of themselves magnetic, and that every particle, as it places itself across the line of magnetic power, acquires a similar force, and exerts it upon all contiguous particles; or that we have arrived at the knowledge of two forces mutually repellent of each other. I cannot avoid entertaining the idea, that these results seem to point to an influence exerted along the magnetic axis, in magnets of the horse-shoe shape, although probably inferior to that "current," which, according to Ampère's theory, circulates around the poles. We have

seen that this influence is capable of being bent out of the line of force by the proximity of a body of the magnetic class, although not a magnet in the usual acceptation of the term. We shall have, however, to consider eventually the manner in which the chemical, crystalline and molecular forces react upon magnetic power; and it is highly probable that we may, by a more extensive examination of the subject, arrive at the knowledge of some disposing forces, or peculiar properties of matter different from those with which we are at present acquainted.

16. In my paper on this subject already mentioned,* I have described an experiment, in which silver was precipitated from its solution by the proto-sulphate of iron, and I have there mentioned and given a drawing of two curiously formed curved spaces, crossing the curves produced by finely divided silver. In my first experiments, the protosulphate of iron was placed on the glass plate in the centre of the poles, and the solution of silver poured over it, and then the above-mentioned curves commenced from the dissolving salt, and proceeded in the line of the magnetic curves towards the opposite pole, being checked at a short distance from it. I have since found that the experiment is much more satisfactorily tried, by filling two tubes closed at one end with a saturated solution of the iron salt, and then inverting these over the poles, and steadily supporting them there during the experiment. By this means the heavier fluid (sulphate of iron) is gradually diffused through the lighter one (nitrate of silver) for a considerable distance around the magnetic poles. When the experiment is made in this way the result is as follows:—

Fig. 8.



The first action, which takes place very slowly, is shown by a cloudiness around the poles, which gradually arranges itself in curves radiating

* Philosophical Magazine, January, 1846, vol. xxviii. p. 4.

from the centre, at first in straight lines, but which are gradually bent into the forms represented in the figure. The exposure of the fluid containing the iron salt for some hours to the action of the air, naturally gives rise to the formation of some oxide of iron. This is gradually deposited in circles around the poles, covering the curves of silver, and, indeed, by involving the particles as they are precipitated, carrying them down with them; thus preventing the formation of any curves of repulsion. It is exceedingly interesting to observe the progress of the true magnetic action, preventing any further development of the diamagnetic power, and at length so far overcoming it as to force the metal (silver), which is powerfully repellent to magnetic influence under natural circumstances, into obedience to magnetic energy. Other cases will be mentioned in which similar antagonistic powers were observable.

17. A solution of *sulphate of copper* being put on the plate, small glass tubes filled with a solution of caustic potash were fixed over the centre of the poles of the magnet. The oxide of copper radiates in straight lines from around the tube, with scarcely any tendency to bend at all except where those lines, springing from the one pole, approach those thrown off from the other. A very decided repulsion then takes place, a line is protected from the deposit of any of the oxide, and the radiations are all bent back.

18. *Muriate of tin* was employed in the same manner as the cupreous salt. The oxide of tin, formed by the action of the alkali, had a tendency to arrange itself in the curves of repulsion, but this was at all times exceedingly weak, and in several experiments it was impossible to detect any regular arrangement. When we employ great battery power and very dilute solutions, the curves are more manifest. On breaking connexion with the battery, they are immediately destroyed; and if we alter the direction of the current, the curves bend in the reverse direction.

19. These curves of the oxide of tin show, in a very striking manner, a remarkable pulsating action during their formation, as if the oxide of tin was thrown off by a series of waves flowing from the magnetic poles. These waves are very uniform, and possibly arise from the exertion of the two forces in opposition to each other: the movement being dependent on the impulse given to the accumulating diamagnetic mass by the concentrated action of the checked power of the electro-magnet as it overpowers the antagonist force. I have observed the same waves, or fits of action, with permanent steel magnets.

20. *Iodide of tin* exhibited nearly the same phenomena as the oxide.

21. *Purple of cassius*, which was formed by filling tubes with chloride of gold, and inverting them in a solution of muriate of tin, presented

an arrangement precisely similar to that shown by the oxide, but the curves formed were more permanent in their character.

22. *Oxide of gold* shows a similar diamagnetic arrangement, but there appears to be less tendency even to any regularity of form, than with the tin. In many respects the oxide of gold and that of tin, under the influence of the magnet, strikingly resemble each other; and, from numerous experiments made with both, I am inclined, at present, to regard their diamagnetic conditions as very similar.

23. Gold, precipitated by the protosulphate of iron from the neutral chloride, has invariably fallen without any appearance of either attraction or repulsion, excepting strong solutions of iron were used, when it was attracted by the magnetic poles; but this was evidently owing to the presence of a truly magnetic salt.

24. *Chloride of platinum* and *nitrate of potash*, forming a double salt, exhibits some obedience to magnetism whilst in motion, but under no other circumstances. It then forms some curves of rotation, but these accumulating on each other are speedily obliterated.

25. *The oxide of platinum*, precipitated by an alkaline salt, invariably gives curves of repulsion during the time the mixing of the two solutions is going on; but when this disturbance is over there is a gradual accumulation of the precipitate about the magnetic poles. I am inclined to regard the diamagnetic curves, first formed, as depending on the potash or soda employed, particularly since Dr. Faraday has, by his experiments, placed platina amongst magnetic bodies, and sodium with those of a diamagnetic character.* This metal, like gold and tin, does not appear to exhibit any very decided property. Further experiments, with a view of determining their conditions still more accurately are, however, contemplated.

* The following list has been given by Professor Faraday:—

Magnetic.	*Diamagnetic.*
	Bismuth.
	Antimony.
	Zinc.
	Tin.
Iron.	Cadmium.
Nickel.	Sodium.
Cobalt.	Mercury.
Manganese.	Lead.
Chromium.	Silver.
Cerium.	Copper.
Titanium.	Gold.
Palladium.	Arsenic.
Platinum.	Uranium.
Osmium.	Rhodium.
	Iridium.
	Tungsten.

26. *Chloride of bismuth* was placed in tubes, which were inverted in the plate, filled with distilled water, over the poles of the magnet. A series of circles were immediately produced corresponding to the iron of the electro-magnet and its coils of copper wire. The quantity of sub-salt increasing, a series of very distinct diamagnetic curves formed, which exhibited a powerful repulsive force, as those from the north pole approached those radiating from the south. These curves were, however, sometimes bent back, and at others doubled down, and exhibited a tendency to unite with curves proceeding from the other side of the same pole. Numerous experiments were made with the hope of tracing these dissimilar actions to some definable cause, but as yet this has not been determined. It may, in all possibility, be dependent upon the magnetic influence exerted on the fine particles in motion within the sphere of powerful action, they being at the same time repelled by the force of the opposite pole. The consequences, under such circumstances, would probably be that the curves of radiation, forming near the axial line, would be driven across it, or turned back, according to the accident of the precipitated subchloride of bismuth being formed at the moment when the magnetic pulsation or oscillation is at a minimum ; or when it arrives at or is advancing towards its maximum ; or by crossing certain nodal points occurring between the successive and periodic impulses. We have, however, such curiously complicated actions to deal with, that we cannot, in the present state of the inquiry, without any knowledge of the laws which regulate the magnetic and diamagnetic forces, venture to do more than assume the possibility that our hypothesis indicates something like the cause of the effects described.

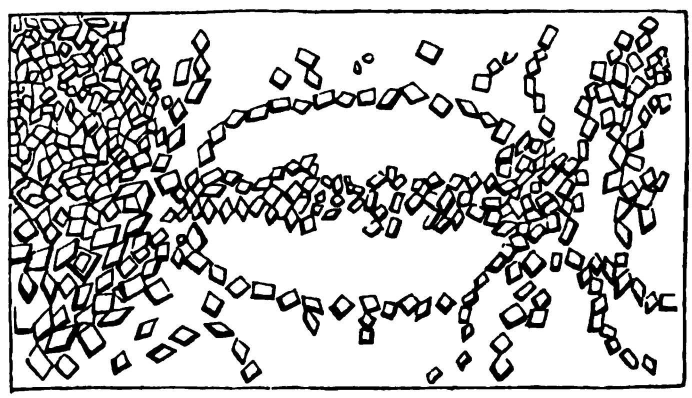
27. *Nitrate of bismuth* shows the same order of arrangement, and the same peculiarities, as those just described (26).

28. A few experiments have been made with the oxides and salts of antimony, zinc, and lead. They all appear to give the same curves of radiations; but as further experiments are intended upon these, and other metals of the same class, any notice of them is for the present deferred.

29. A warm saturated solution of the protosulphate of iron being poured in a copper dish, was placed, as in the other experiments, over the poles of the electro-magnet. As the solution cools, a gradual formation of crystals takes place, and if the proper strength of solution be hit, the necessity for which will be presently explained, the crystals arrange themselves in magnetic order,—that is, along the axial line, they form numerously, and in the experiment, the result of which is represented in Fig. 9, they arranged themselves in two well-defined lines extending, on either side, from one pole to the other. Crystals accumulated abundantly on the poles, and some indications of a ten-

dency to form other magnetic curves were shown. A very remarkable quantity of crystals formed near the north pole, compared with those about the south pole; the crystals near the north being, however, much smaller, and less perfectly defined than the others.

Fig. 9.



30. If a very strong solution be employed, the crystals arrange themselves without any apparent reference to the magnetic force; and if a solution of the same strength as the one giving crystalline curves, when the electro-magnet is connected with a strong battery, be placed on the poles when the battery current is much weaker, and consequently the magnetic force diminished, no magnetic curves will be formed by the crystals. We thus arrive at the very curious fact, *that the magnetic force may be made to restrain the crystalline power;* or that the natural polar forces of crystals may be too strong to be affected by magnetic influence.

31. Under every circumstance yet tried, both as it regards the strength of solutions, and the power of the magnet, the crystals formed have been much more perfect than those produced in comparative experiments, which have always been made independent of the influence of the magnet.

32. The crystals of sulphate of iron, crystallizing under ordinary circumstances, unite by their faces; but when the crystallization takes place within the influence of magnetism, they unite in a different manner. Sulphate of iron crystallizes in oblong rhombic prisms; and it appears that the general tendency of these, when forming within the sphere of magnetic influence, is to arrange themselves, with regard to each other, so that the acute angle of one crystal unites with one of the faces of

another crystal near to, but never actually at, the obtuse angle, as is shown in the sets represented (Fig. 9). This would appear to indicate a turning round of the crystals, so that the line of magnetic force should pass along a line running through and across them, by the obtuse angles in one case, and the acute angles in another. There can be no doubt but that these results point to some general law of arrangement, which may be, by a far more extensive examination of the subject than has yet been made, at length, discovered.

33. We have been in the habit of considering certain metals magnetic, whilst all the others have been regarded, until the recent researches of Dr. Faraday have shown the contrary to be the case, as without any influence allied to the magnetic. We now know that there is a class opposed to the magnetic class, and which, as it appears, are not merely repelled by magnetic bodies, but have themselves equally strong powers of repulsion. Under this conviction, it at once occurred to me that the crystals of sulphate of iron forming on glass or copper, both diamagnetic bodies, should present something different from those forming on a plate of iron, or in any magnetic vessel. The result of several experiments proves that crystals of a magnetic body forming on a plate of metal, which belongs to the magnetic class, are less regular, and of a smaller size than those formed on a diamagnetic one; thus proving, although we have no manifestation of magnetism, as ordinarily shown by its attractive and repulsive power, that a peculiar indication of the existence of powers allied to those under consideration is given by the results obtained by crystallizing salts under different conditions.

34. Sulphate of copper being allowed to crystallize under similar conditions to those observed with the sulphate of iron, it was found, if a strong solution was employed, and, consequently, if the crystallization went on quickly, that they covered the plate pretty uniformly; but if, by using a weak solution, the force which determines crystalline form was diminished, and the crystallization went on slowly, within the influence of an electro-magnet of considerable power, a very regular order of arrangement was constantly observed. A well-defined circle of crystals appears around the poles, but at some distance from them, within which are perfectly free spaces. At equal distances from either pole an abundant crop of large crystals form, and there are indications of radiations from this point shown by crystals forming along lines which are curved away from either pole, as if by some mutually repulsive force. These two salts may be considered at present as the representatives of the two classes of crystalline bodies,—the magnetic, the protosulphate of iron; the diamagnetic, the sulphate of copper. In the former, we observe the crystallization marking out the lines of magnetic force; in the latter, we see an evident tendency to cross those lines, the crystals arranging

themselves according to some influence which is evidently opposed to the magnetic power. A very extensive series of experiments will be necessary to the elimination of the law of these forces.

35. In every experiment I have been struck with the difference in the quantity of precipitate which collected, or crystals which formed around the two poles of the magnet; a larger quantity, in all cases, accumulating about the north, than about the south pole. This was so very different from our preconceived notions of the condition of a magnet, in which we have been led to regard the powers in a state of equilibrium, that it demanded a careful investigation.

36. The superior power of one pole of a magnet has been, I find, on several occasions, mentioned by the elder magneticians, and Ritter published a statement of experiments, corroborated by Œrsted,* in 1828. After stating that its action on frogs was similar to that of a galvanic pair, Œrsted says:—"Ritter plaça un fil de fer aimanté, dans un plat de faïence, il y versa de l'acide nitrique très faible: le pôle méridional fut beaucoup plus fortement attaqué par l'acide que le pôle septentrional, et se trouva aussi entouré d'un dépôt d'oxide beaucoup plus tôt." Other experiments are described in the same paper, but they do not appear to have had that attention paid to them which they deserve, related as they are to a correct knowledge of the magnetic power, and pointing, probably to some law of action which is not indicated by any theory received at present by the scientific world.

37. With a view of determining the question, I instituted a series of experiments. I intend extending them as far as possible, with every modification of circumstances which may suggest themselves to me, but at present I am only enabled to announce the following facts. The method employed by me will be understood from the following figure (Fig. 10).

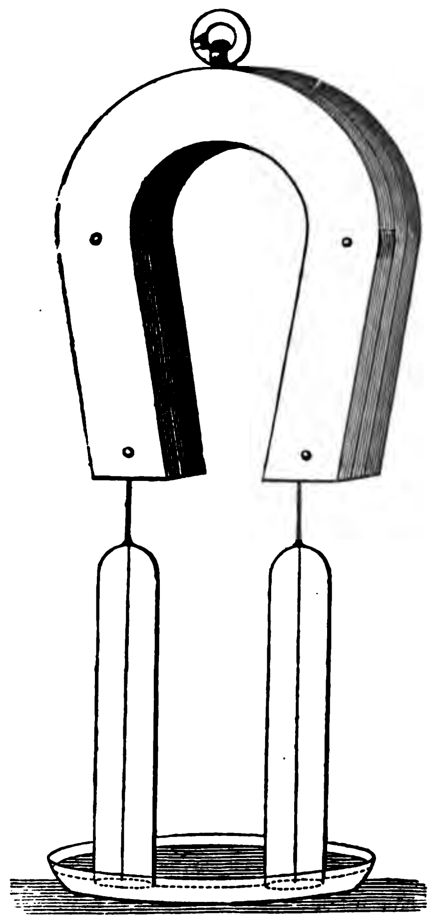
Iron wires are cemented into glass tubes; these tubes are filled with the substance in solution to be examined, and being inverted in a vessel of the same solution, the projecting ends of the wire are suspended from the poles of a permanent horse-shoe magnet, by which, of course, these wires, under the influence of induction, become magnets: a north pole being in the solution on one side, and a south pole on the other.

38. When a solution of sulphate of copper was employed, it was found invariably that the largest quantity of copper was deposited about the wire from the north pole: the difference in quantity between that and the metal about the south pole, depending upon the amount of chemical action which is established during the process of substitution.

39. If sulphuric acid was added to the solution of sulphate of copper,

* Annales de Chimie et de Physique, vol. xxxviii. p. 197.

Fig. 10.



by which the action of the iron was quickened, the difference in the quantities of copper at the poles of the magnet was diminished.

40. If dilute sulphuric acid alone be used, hydrogen gas is of course liberated from the solution by the oxidation of the magnetic wires. In this case the reverse of the above effects results, and the largest quantity of hydrogen gas appears at the south pole. In this instance, as in the other, the difference between the quantities liberated at each pole depended upon the quantity of acid in the water; thus proving, although magnetism exerts a very decided power upon chemical action, that the forces of affinity, may be so great as to overpower the magnetic force.

41. The physical investigation of this very curious subject belongs properly to another inquiry, but still it must, if the phenomena are con-

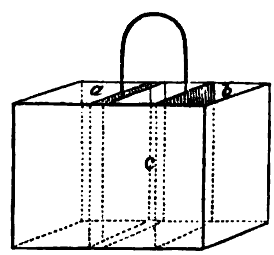
stant, have such an important bearing on the subject of this paper, that I have thought it advisable to describe these experiments. The laws of magnetic action, as they are distinguished, if different, from those of voltaic electricity, it is most important to learn. This great force, as developed in nature, and exhibited in all the phenomena of terrestrial magnetism, must influence the conditions of structure, and the arrangements of the masses of the rocks constituting the crust of the earth.

42. It occurred to me that the position of the wires might have much to do with the observed differences. Experiments were therefore made in which the magnets were inverted, and also in which they were placed in the magnetic meridian in the direction of the dip. The results were, however, under all these circumstances the same, the largest quantity of metal appearing at the north; the greatest measure of hydrogen gas being found in all cases at the south pole.

B.—INFLUENCE OF VOLTAIC ELECTRICITY.

43. The earliest experiments with which I am acquainted, showing the tendency of electrical currents to produce a determinate arrangement in the particles of matter, were by Mr. R. Were Fox and Mr. Thomas Jordan.* Of these the following experiments must be considered merely a repetition, but they have been extended from clays which were the only materials on which they operated, to sandstones, plaster of Paris, and other substances. The manner in which these experiments were tried, will be understood from the following description of the arrangements employed. An oblong box was divided in the centre

Fig. 11.



by a wall of clay (*c*) three or four inches in thickness, or by any other body on which it was thought desirable to try the experiments. A zinc and copper plate (*a b*) connected by a band of copper was then passed down into the box on either side of the clay, and the voltaic pair brought

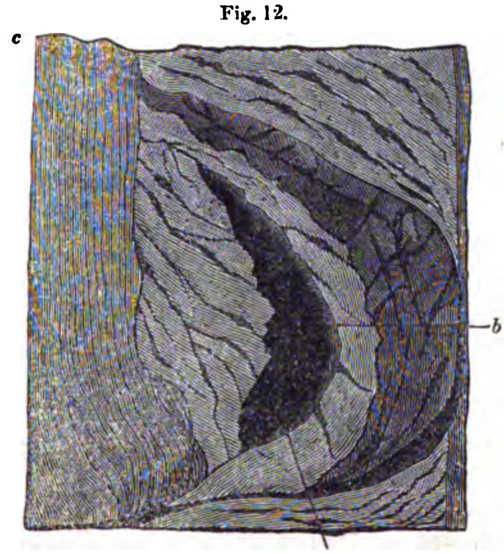
* Reports of the Royal Cornwall Polytechnic Society, No. 5, 1837, p. 68; No. 6, 1838, p. 169. The view entertained by Mr. Fox will be gathered from the following :—"Indeed, the general laminated structure of the clay appears to indicate that a series of voltaic poles were produced throughout the clay, the symmetrical arrangement of which had a corresponding effect on the structure of the clay.'

into action by filling the trough with some chemically exciting fluids. The electricity thus excited passed by the copper connecting band to the copper-plate, and returned through the interposed mass, placing it in similar conditions to those we may imagine to prevail in nature.

44. Several arrangements of this kind have been made. Stourbridge clay, plaster of Paris, sandstone (the ordinary Bath scouring brick), and finely powdered coal have been used for the dividing mass. The exciting fluids have been diluted sulphuric acid in both cells. Sulphate of copper in one (the copper) cell, and muriate of soda in the other, or sulphate of iron and muriate of ammonia. In general the voltaic action has been kept up for a month or six weeks to its first power, by a daily attention to the solutions, after which the fluid has been allowed to evaporate slowly away.

45. Masses of clay subjected to this action were found after some months to have assumed the conditions mentioned by Mr. Fox. On the side next the zinc plate, distinct lines of cleavage of a schistose character, parallel to the sides of the clay and the plate, or at right angles to the direction of the current presented themselves. These laminæ, on drying the mass, were gradually contorted, and at length broken off. On the side next the copper plate instead of the laminated, structure, we find a consolidation of the mass; this consolidation appearing to take place in the direction of the current or very nearly so. The induration in many cases is very striking. In one experiment made with great care upon a mass of clay, weighing several pounds, where the action was continued from July 4th, 1845, to January 20th,

Fig. 12.



1846, and then allowed slowly to dry between the galvanic plates, the results were so curious as to merit a particular description (Fig. 12).

46. On the zinc side, to the depth of an inch and a half, there were distinct lines parallel to the plate, not extending from the top to the bottom of the mass, which was 12 inches deep; but after proceeding about six inches down, exhibiting a tendency to bend inwards. Upon breaking the clay open when dry, it was found that after proceeding towards the centre of the mass they again turned outwards, and formed indeed curved lines from one point of the zinc plate near the middle to its lowest point. The consolidation on the copper side was very distinctly marked, and the appearance was that of a continuation of hard nodular masses along the lines of the voltaic current. This consolidation had evidently been produced by the drawing of particles from the centre of the mass, in which a large hollow (*a*) was formed; and this was found to be a portion of a very decidedly marked line of action from the bottom of the zinc plate to the centre of the copper plate (*b*), and from that point again to the top of the zinc plate (*c*). As these curved lines approached the zincous side, they were crossed and split by laminations, although very distinctly continued. We have thus evidence afforded us of two distinct forces in action, or perhaps it would be safer to say, indications of two lines of power along which the particles arrange themselves. It was found, upon close examination, that the curved lines above described were formed by the metallic copper, and the carbonate of copper and zinc—(sulphate of copper was used on the side of the copper plate, and muriate of soda on the zinc side). Upon breaking the clay transversely, the appearance of the mass was in the highest degree interesting and instructive. From near the top on the zinc side, a marked dark space was seen to describe a line inclining from the horizon at about the angle of 40. When it approached the copper side, it was gradually bent back, and formed a curve to the bottom of the zinc plate. This curve was formed in parts near the copper plate of laminæ of metallic copper, whilst more distant from it specs of carbonate of copper appeared which were particularly confined to the marked space, and indeed represented an artificial mineral lode.

47. A difficulty at present presents itself which will no doubt disappear when we have had the experience of further investigation. This is to account for the arrangement of the particles of clay in parallel planes, according to the order of the diamagnetic curves, and of the disposition of the metallic salts, and metals themselves, even of those which are not magnetic, zinc and copper, along what appears to be the true circuit of the electric current.

It was observed very soon after the experiment just described was first established, that the fluid on one side was elevated considerably

above the fluid on the other; this is the well known exosmose always observed during electro-chemical action. But in this case the mass of clay was elevated on the same side, and this went on increasing until the fluid was dried off. This may have been merely mechanical, but the fact is curious in itself and worthy of notice as it may lead to the explanation of some movements of solid matter under circumstances of apparent difficulty. Other experiments have proved to me the possibility of raising comparatively large masses of matter by the agency of current force or the dynamic power of voltaic electricity.

48. A number of nodules were formed in the clay in this instance, and it is curious to observe that all these concretions arrange themselves along the line of the current. In nature they are mostly found in some given direction parallel to each other; and, from the indications we have thus obtained, it is probable that we shall find their order determined by some local electrical influence.

49. A thin paste of plaster of Paris was placed between similar plates of zinc and copper, which were excited by diluted sulphuric acid. This action was kept up for about three months, and then allowed to dry off. On becoming quite dry, it was found that the gypsum was laminated to the depth of an inch on the zinc side and indurated considerably on the copper side.

50. An ordinary Bath brick used for scouring cutlery—a siliceous sandstone—was placed between a zinc and copper plate, in a similar voltaic arrangement to those already described, the current being excited by a solution of *salt* (muriate of soda) on the zinc side, and sulphate of copper on the copper side. The lamination was very decided to the depth of more than half an inch, from which, to the middle, the brick remained unchanged, whilst on the copper side the general induration had taken place, as in the other examples. Copper had passed through the brick, and it presented itself in the form of carbonate on the zinc side, running across the lines of lamination. This brick had been placed in the trough vertically; it was only on one side that the carbonate of copper was seen, but it extended from a certain point near the centre of that side, increasing in quantity towards the zinc plate, no trace of it being seen on any part of the brick, near the copper plate, except a thin lamina of it between the plate and the sandstone. As the laminæ dried, they became very much contorted, and were gradually broken off from the mass.

51. A similar brick was placed horizontally between a copper and a zinc plate, excited as before. After the action of about four months, it was dried, when it was found to have cracked from near the bottom of the zinc plate to the top of the copper plate, separating into two nearly equal parts. This fracture corresponded in direction very nearly

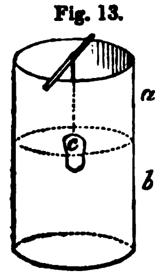
same lodes, divided by a fissure or cross course. In East Pool mine I succeeded in obtaining the decomposition of iodide of potassium by the current circulating through the wires; but Mr. Fox has since then succeeded in forming at Pennance Mine, near Falmouth, an electrotype in copper, from the current circulating through two wires connected with two dissimilar lodes, which were brought to the surface and dipped into a vessel containing sulphate of copper.*

57. That these currents are not due to any chemical action excited at the points of contact between the conducting wires and the ore of the lodes, is proved by the fact, that whether plates of platina, or of copper, or of zinc, were employed in making contact, the current observed a constant direction. That the electricity may not be due to chemical decomposition going on within the lode itself, is less satisfactorily made out.

That the ordinary sulphurets of copper in Cornwall are exceedingly liable to decomposition may be readily proved by the following simple experiments.

58. If we put into a cylindrical vessel a solution of sulphate of copper, and float upon it a weak solution of any alkaline salt, and then suspend a piece of yellow copper pyrites (a double sulphuret of copper and iron†), so that one portion is in the metallic solution (*b*), and the other in the alkaline solution (*a*), in a very short time a change of colour will be observed over that part of the ore in the copper solution, but not over any other part. After a few days, the change still going on, a deposit of peroxide of iron will be found around the vessel, at the surface of the denser fluid. The following form of the experiment will show that this is set free from the part undergoing decomposition.

Fig. 13.



59. Two pieces of copper pyrites being connected with a constant voltaic battery of Daniell, were placed in a solution of the muriate of barytes (Fig. 14). Within a few hours sulphate of barytes was precipitated, and the ore connected with the copper pole became beautifully

* See Reports of the Royal Cornwall Polytechnic Society for the years 1842, 3, 4.

† Specific gravity . . . . 4·3

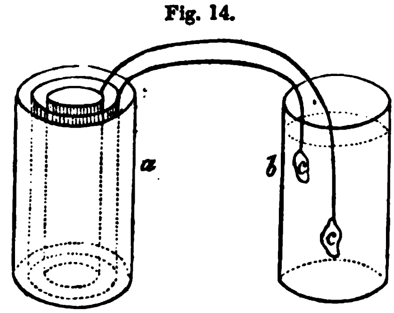
Copper	30·00
Iron	32·20
Sulphur	35·16
Earthy matter	0·50
Arsenic and loss	2·14

Analysis of a crystallised specimen by Mr. Richard Phillips, of the Museum of Economic Geology, given in Philips's 'Mineralogy.'

iridescent. After the action had been continued for some weeks, the following results were obtained:—

The piece of copper pyrites connected with the copper pole was changed over the entire surface into the gray sulphuret of copper. Of course this change was effected by the liberation of the sulphur and iron. The sulphur, at the moment of liberation, uniting with oxygen, is converted into sulphuric acid, which, combining with the barytes, forms the insoluble sulphate, of which 29 grains were collected, showing the presence of 10 grains of sulphuric acid, or the liberation of about four grains of sulphur, or the separation of nearly 10 grains of the sulphuret of iron from the ore. This iron was found partly in the solution, as muriate of iron, and partly as peroxide of iron, deposited over the unchanged piece of ore connected with the other pole of the battery.

Fig. 14.



60. Changes of this kind are constantly going on in nature, and we find numerous mines in which the progress of these decompositions can be traced. At Dolcoath copper mine, by some local action a portion of the lode, near a "cross course," was converted into the gray sulphuret of copper; all other parts remaining in its original state of copper pyrites. Over the portion thus changed the prevalence of peroxide of iron was very marked. The same thing is observed in the Carn Brea mines. The decomposition is not confined to the iron of the ore, but is continued to the destruction of the sulphuret of copper itself. I have detected in water flowing from the junction of the granite and clay slate (Killas), at the 80 fathom level in the Consolidated Mines, Gwennap, 1·25 grains of sulphate of copper in every 1000 grains of water.*

61. Whenever any changes of the kind described occur, it is evident that there must be a large quantity of electricity set in motion, in the form of a current. Dr. Faraday has beautifully shown "that the elec-

* For a description of the various conditions of the metalliferous veins of Cornwall, see 'Geological Report on Cornwall, Devon, and West Somerset,' by Sir Henry De la Beche, chapters x. xi. xii. p. 283–394.

tricity which decomposes, and that which is evolved by the decomposition of a certain quantity of matter, are alike.* We are, therefore, led to the conclusion, that the electricity engaged in this decomposition is due to some peculiar action upon the crust of the earth by some of the radiant forces, and that the electricity measured, or capable of being measured, in the experiments on the electricity of mineral veins, is an exact representative of the amount of chemical action going on within the mineral vein or lode itself.

62. That there is a very striking relation between the electricity thus evolved, and magnetism, is shown from the following experiment. Two pieces of copper pyrites were connected by copper wires with a Daniell's battery, and placed in a mass of clay in a moist state. The clay dried very slowly, and when quite dry presented sundry cracks, all radiating, somewhat irregularly, from around the wires. The ores had changed, as in the case already described (58). On breaking the clay, it was found that it was arranged in curved lines; those from the north pole being exactly at right angles to those produced by the action from the south pole.

63. It would be very premature to attempt, at this period of the investigation, to explain the phenomena which have presented themselves. Many things remain to be proved, and although we have seen that magnetism and electricity are capable of producing the same effects, we have yet to add that link to the chain which will prove the relations existing between the forces of chemical affinity and magnetism.

64. The experiments on the temperature of mines, &c., sufficiently prove some source of heat beneath the surface of the earth, which, by acting at considerable depths, must be capable of producing upon a given mass of matter certain effects analogous to those of a thermo-electric bar. At the same time, we have the action of radiant forces on the surface, to which possibly the magnetism of the earth may be due. Professor Airy is disposed to refer it to the influence of the solar calorific radiations;† but it may probably be due to the influence of the actinic power, or that force which is active in producing chemical change, particularly as we must refer to it those effects on magnetic needles observed by Mr. Christie and others.‡

65. From the results of the experiments which have been now described, a most intimate relation is indicated between the crystalline and molecular forces, and magnetism and electricity. This relation, it would appear, must also be extended to the phenomena of chemical

* 'Experimental Researches in Electricity,' vol. i. p. 256.

† 'Evening Lecture on Magnetism at the Meeting of the British Association at Cambridge,' reported in the 'Athenæum.'

‡ 'Philosophical Transactions,' 1826, p. 219.

attraction. The links wanting to connect the radiant forces and the powers which pervade all material creation, regulating the disposition of particles and the forms of matter, seem to be near their developement; and if the researches of modern science are pursued in the path to which the investigations of Faraday in particular have afforded the clue, it is probable that more will be learnt of those secret powers which regulate the laws of creation.

On the Gases evolved during the Formation of Coal. By Dr. Lyon Playfair, F. G. S., Chemist to the Geological Survey of Great Britain.

It may be some time before we fully understand the processes in operation during the conversion of woody fibre into the curious chemical compound, coal. The only way of attaining such knowledge is to examine carefully the gases eliminated during its progressive alterations, and endeavour to follow out the proximate changes which have produced these ultimate products of transformation.

The gases arising from coal, and obviously due to the changes undergone by woody fibre, are too well known in our coal districts by their explosive nature. The researches of Bischoff have shown them to contain, in addition to carburetted hydrogen and carbonic acid, olefiant gas, which would seem to indicate that the gases are products of distillation, not those of decay. The determination of this point was of great importance, and I have, therefore, entered into a detailed inquiry, having subjected to rigid analysis gases collected from many mines in different localities. When this examination had been nearly completed, researches on the same subject were published by Professor Graham, whose previous inquiries had rendered him admirably fitted to undertake analyses requiring so much delicacy.

The results obtained by this chemist have been communicated to the Chemical Society.* The general result of his analysis confirms the views formerly entertained of the composition of the gases, namely, that they form a mixture of light carburetted hydrogen, with a small mixture of nitrogen and oxygen, as common air, but that they neither contain olefiant gas, nor carbonic acid, both of which Bischoff had found in gases from mines in Germany.

The mode in which the gases were collected by myself was very simple. A tube was introduced into a blower of gas, and connected with a series of glass tubes four inches long, and three-quarters of an inch wide, drawn out at both ends and connected with each other, and also with the conducting tube, by caoutchouc joints. When the gas had blown through this system of tubes sufficiently long to displace the atmospheric air, the contracted portions of the glass receiver were sealed by means of a blowpipe. This could not be effected on the spot itself, except in a few instances, where danger was not to be apprehended, but was done after-

* Memoirs of Chemical Society, vol. ii. p. 7.

wards, each caoutchouc joint having, in the mean time, been made air-tight by being closely tied. When I did not collect the gas, but intrusted its collection to other hands, it was necessary to employ the pneumatic method. However, there was an error in this mode of collection which could scarcely be avoided under the circumstances. The water used in the trough and flask dissolved the carbonic acid contained in the gas, and hence Professor Graham has been led to deny its presence, although it always exists in notable quantity in the gases collected in the dry way.

The methods employed in the analyses of the gases are those invented by Professor Bunsen, and described in our report to the British Association on the smelting of iron. These methods are, perhaps, the greatest additions to analytical chemistry, with which it has been enriched in modern times, and as they are yet quite unknown in this country I shall describe them in some detail, since their success entirely depends upon proper attention being paid to the most minute precautionary means for ensuring accuracy. In describing these as proposed by Bunsen himself, I will give at the same time some additional means for more surely attaining the desired end.

The eudiometers used in the inquiry were 18 inches in length, being 0·6 inch interior, and 0·8 inch extérior, diameter. In the closed end two platinum wires are inserted by fusion for the purpose of passing the electric spark. This tube is divided into arbitrary divisions on the outer surface, these being, for the sake of convenience, millimètres, and the calibre of the tubes, at different parts, is exactly taken, in order to determine the precise relative value of each of the divisional marks. The tube is calibrated by pouring small portions of mercury successively into the eudiometer placed in a vertical position. After each addition, the air bubbles adhering to the walls of the eudiometer are removed by an iron wire, and the position of the mercury read with the aid of a mirror, which is fixed to the tube, and the reading is considered exact when the pupil of the eye seen in the mirror seems halved by the mark corresponding to the convexity of the mercury. These additions of mercury and determination of volume are repeated until the eudiometer is quite filled. The numbers thus obtained express one, two, or more times of a number fixed upon as unity, so that it is easy to calculate how much each mark or millimètre corresponds to that taken as unity. From these numbers a table is constructed, out of which we obtain the true value of the uncorrected volumes obtained by reading from the eudiometer. In this method the assumption is made that the small parts of the tube corresponding to each addition of the mercury is in itself uniform; and although this may not be absolutely true, still any error arising from this circumstance must entirely disappear, if the

tube selected for the eudiometer be tolerably uniform in its dimensions, and if the parts taken in determining the calibre be sufficiently small, that is, if the mercury employed in each addition be only sufficient to include ten millimètres. With a little practice, aided by the mirror, it is easy to read to the one-tenth millimètre, so that the table of corrections constructed from the calibre of the tube must be carried out to this amount.

In most eudiometrical analyses of mixed gases, a shorter tube of $\frac{3}{4}$ foot is required, which is divided, and the calibre taken in the same manner as the large eudiometer, but it is not supplied with platinum wires. This tube is used for removing carbonic acid, sulphurous acid, &c., from the gases previous to their combustion with oxygen. If the determination of these were effected in the large eudiometer, it is impossible to prevent a little potash adhering to the walls of the vessel, and thus causing a diminution in the volume of carbonic acid produced by the explosion. This evil is entirely prevented by determining the amount of the gases absorbed by potash in a small eudiometer, and afterwards transferring the remaining gases to the larger eudiometer, furnished with platinum wires.

It is almost unnecessary to state, that the analyses were conducted over mercury, which, in fact, is the only substance fitted for the purpose. The mercury was contained in a trough made of mahogany, cut out of the solid wood, and so constructed as not to require a very large quantity of mercury to fill it; 50 lbs. of mercury were sufficient, the length of the trough being $\frac{4}{4}$ foot, and the depth four inches. These dimensions are amply sufficient, not only for the analysis itself, but also for the transference of the gas from one eudiometer to another.

The room, in which the analyses were performed, was exclusively devoted to this purpose, so that it was not liable to any sudden changes of temperature, being protected from the direct action of the sun, although freely exposed to diffuse light. The table for the trough was placed near the window, so that the eye might be opposite the light during the readings. In filling the eudiometer with mercury, a funnel with a long neck, terminating in a narrow opening, was used, and the mercury flowing through this adhered to the sides of the tube with a clear mirror-like surface, which it does not do in the ordinary mode of filling, as small air bubbles are apt to intervene, and introduce inaccuracies into the analysis.

Unless very large quantities of mercury be used, the gas cannot be transferred into the eudiometer from large bottles, and therefore in every instance the small tubes previously described were employed for this purpose. In some cases the gas was contained in common wine-bottles, and was from this transferred into smaller tubes in the following

manner. A tube of about five inches in length, and ¾ inch broad, sealed at one end and drawn out at the other, was connected with a small funnel by means of a caoutchouc joint. The tube and funnel was now filled with water, previously well boiled and still warm, and inverted in a trough filled with the same kind of water; the flask was then introduced into the trough, and the gas made to pass through the funnel until the tube was filled, after which its narrow end was hermetically sealed by the flame of a blow-pipe. When the gases were explosive, the caoutchouc joint was closed with thread, and afterwards dipped into wax. Sufficient guarantee for the efficiency of these methods is given by the circumstance, that gases collected in this manner did not contain an appreciable quantity of oxygen. From these little tube receivers the gas is easily transferred into the eudiometer filled with quicksilver, by dipping it under mercury, removing the point by pressure against a file, and allowing the bubbles of gas to ascend slowly into the eudiometer.

In all estimations of the gases, it is necessary either always to operate with them perfectly dry, or thoroughly saturated with aqueous vapour, in order that we may be able to make the necessary corrections for the increase in volume occasioned by the tension of the vapour. When the gas is not of such a nature that the presence of aqueous vapour is either accidental or improbable, it is convenient at once to take the measurements at the maximum of moisture, especially after the transference of the gas from the smaller to the larger eudiometer. This may easily be effected by putting a drop of water, about the size of a pin's head, on a wire, and introducing it into the top of the empty eudiometer, detaching the drop from the wire by drawing it along the sides. When the eudiometer is afterwards filled with quicksilver, and the gas subsequently introduced, the latter becomes saturated with aqueous vapour, at any desired temperature.

In measuring the volumes of the gases it is quite necessary to hold the eudiometer in a strictly vertical position, and this may easily be accomplished by placing the tube parallel with two perpendicular lines, separated from each other, and used for the purpose of comparison. The eudiometer being thus placed in a vertical position, the volume of the gas must quickly be read off by the mirror previously described, because the heat radiating from the body, or that coming from contact of the hand, very speedily augments the bulk.*

A second reading is necessary for the purpose of determining how

* In reading the volume, a correction must be made for the parallax of the mercury. The eudiometer having its sealed end downwards during the calibrating, has its convexity in a contrary position to that exhibited in the analysis of the gas. The neglect of this circumstance would cause a notable error in the result. The amount of correction due to the reversing parallax of the mercury, may simply be determined for each eudio-

high the surface of the mercury in the eudiometer is above that of the mercury in the trough. This reading may be determined with sufficient accuracy by allowing a bent piano wire to float on the surface of the mercury, and bringing it in contact with the eudiometer: the divisional mark touched by the wire is the height of the mercury in the trough. The difference between the upper and lower readings must be deducted from the column of mercury in the barometer. The advantage of making this correction is, that there is no contact of the hand or displacement of the eudiometer in depressing it in the trough, so as to make the inner and outer levels of the mercury correspond.

The pressure of the atmosphere was determined by an excellent barometer furnished to us by Newman; this barometer was divided into millimètres, and we could accurately read to $\frac{1}{10}$ mm. Beside this barometer hung a very delicate centigrade thermometer, with which $\frac{1}{10}$th of a degree could be read with precision.

Having stated these preliminary precautions, I now proceed to describe the methods adopted in the analysis of the gases. The gases which were likely to be present were oxygen, nitrogen, carbonic oxide, carbonic acid, olefiant gas, light carburetted hydrogen, and hydrogen. Their accurate determination offered no difficulties. I had previously convinced myself that not a trace of sulphuretted hydrogen accompanied the gases, for the gas being allowed to blow through a solution of acetate of lead for several hours, produced not the slightest discoloration.

It is proper to mention that instead of using aqueous solutions for absorption, the absorptive materials were in the form of little pistol bullets, made by inserting a piano wire into a pistol bullet-mould, and pouring into this the substance in a fused state. The carbonic acid was determined by means of a little bullet of caustic potash in the following manner:—A certain quantity of gas was introduced into the small eudiometer, formerly described, and its volume determined with the proper precautions. The bullet of caustic potash was now introduced by its attached wire, and the end of this iron immersed under the mercury. This last precaution is absolutely essential in all cases of analysis, because if it be not attended to an endosmose and exosmose takes place to such an extent as to destroy the value of the analysis. As soon as the bulk of the gas ceases to diminish, the ball of potash is carefully removed, and the inner and outer surface of the mercury

meter by experiment. A solution of corrosive sublimate is thrown into the eudiometer, and an adherence is now effected between the walls of the vessel and mercury by the formation of calomel. The surface of the mercury is now horizontal, and the difference of readings is determined. This correction may be used, in all subsequent cases, for the same eudiometer without further experiment, but it must never be neglected.

determined. The gas has now been deprived both of its carbonic acid and aqueous vapour.

The next determination is of the olefiant gas, and is effected by strong fuming sulphuric acid. An intimate mixture of coal and coke in the form of a pistol-bullet is fastened to a stout platinum wire by a strong continued exposure to the blow-pipe flame, and afterwards to render it sufficiently solid, it is dipped into a saturated solution of sugar, and again strongly heated. Before this bullet has time to attract moisture from the air, it is dipped into a vessel containing a mixture of equal parts of anhydreous and of Nordhausen sulphuric acid, a considerable quantity of which it absorbs without becoming wet on the surface. This bullet, still strongly fuming, is now introduced into the eudiometer, and the volume of gas is observed to augment, partly in consequence of the tension of the anhydrous sulphuric acid, partly owing to the formation of sulphurous acid. After the ball has been for some time in the gas it may be withdrawn, and if it still continues to fume, we feel assured that any olefiant gas present must have been completely absorbed. It is now necessary to remove the anhydrous sulphuric acid, or, by destroying its tension, to convert it into hydrated sulphuric acid, and at the same time to remove any sulphurous acid which may have been formed. Both of these objects are effected by moist peroxide of manganese which is used in the following way:—Peroxide of manganese previously treated with dilute nitric acid, so as to remove any trace of carbonate, is made into a paste with water, and placed in the bullet-mould previously smeared with a little fat, and containing the end of a platinum wire. By allowing this mass to dry slowly, on opening the mould a well-formed and sufficiently coherent ball is obtained. It is now moistened with water and introduced by means of the adhering platinum wire into the gas. The sulphurous acid is now completely absorbed, and the anhydrous sulphuric acid deprived of its tension by conversion into hydrated sulphuric acid. But as it is impossible so to regulate the addition as to prevent the formation of a dilute sulphuric acid, which by giving out aqueous vapours, would increase the volume of gas, it is necessary to introduce a ball of potash attached to a platinum wire in order to remove the watery vapour. Chloride of calcium cannot be used for this purpose, lest muriatic acid should be generated. The volume thus obtained, after the due corrections, compared with that ascertained before the introduction of the fuming sulphuric acid, gives the quantity of olefiant gas present.

The volume of oxygen is now determined, the small eudiometer being still used. For this purpose a ball of phosphorus prepared and attached to a platinum wire in the way already described, is well moistened with water, and introduced into the gas. The absorption of

oxygen is finished as soon as the vapours of phosphorous acid cease to flow from it. But if the proportion of oxygen in the gas be very considerable, the vapours cease before its complete absoption, because the phosphorus becomes covered with a layer of phosphorous acid which prevents the access of oxygen. To obviate this inconvenience, the ball of phosphorus must be removed, carefully washed, and while still wet, be again introduced into the gas. The volume of the gas is augmented by the vapours of phosphorous acid; and to deprive this of its tension, a ball of moist potash is introduced, and this effectually neutralizes the increase. Lest the aqueous vapour should augment the volume of the residual gas, a dry ball of potash may be introduced after the first is removed, but this is an excess of precaution which rarely is found necessary. In all the cases above mentioned the wires must necessarily be platinum, or at all events, amalgamated iron, to prevent the elimination of hydrogen by the action of acids.

The gas freed in the manner described from carbonic acid, oxygen, and olefiant gas is now passed from the small to the larger eudiometer, which has previously been moistened and filled with mercury with the precautions detailed. The volume of the gas introduced being then carefully determined, it is mixed with at least twice its bulk of oxygen. The latter gas is most conveniently prepared by heating pure chlorate of potash in a small retort made by blowing a bulb on a common tube of difficultly fusible glass. After continued heating, when, at least 20 times as much oxygen as corresponds to the volume of the retort has been evolved, it is allowed slowly to pass into the eudiometer, and we are thus fully assured that it cannot be contaminated with common air.

After measuring the new volume thus obtained, the gas is ignited in the usual way by the electric spark. In order to prevent any of the gas being expelled by the heat generated by the explosion, the eudiometer is strongly pressed upon a sheet of caoutchouc at the bottom of the trough. This requires all the strength of the hand, and pre-supposes that the eudiometer is strong enough not to be blown to pieces while we are thus holding it. The explosion of light carburetted hydrogen is so very powerful, and the elevation of temperature so considerable, that the mercury is volatilized and covers the inner wall of the eudiometer with a thin metallic layer. In order to lessen the force of the explosion, it is sometimes necessary to add a known quantity of atmospheric air, the oxygen of which must be added in calculation to the amount of pure oxygen introduced by the fusion of chlorate of potash. This admixture of air is often absolutely necessary, when the proportion of nitrogen is in small proportion to the combustible constituents of the gas, because the intense heat generated by the explosion, causes the formation of nitric acid which is seen in white crystals, as

nitrate of mercury on the walls of the tube. But when the gases have been previously diluted with two or three times their volume of air, no nitric acid is formed by the explosion, and the composition of air being now so well determined, no inaccuracy is introduced into the results. Before the sheet of caoutchouc upon which the eudiometer is pressed during the explosion, is immersed in the mercury, it is moistened with a solution of corrosive sublimate and gradually pressed down. By this means complete contact between the mercury and caoutchouc is obtained by the formation of calomel, and air bubbles are thus excluded which otherwise would be carried down, and being detached by the force of the explosion, would rise into the eudiometer when the tension became diminished. After the explosion the eudiometer is slightly inclined, and the caoutchouc gradually pressed down so as to allow the mercury slowly to rise in the tube and occupy the space formerly taken up by the gases. In pressing down the caoutchouc, care must be taken not to allow the finger to approach too nearly to the opening of the eudiometer, because the current caused by the flow of mercury drags off the layer of air surrounding the finger, and passing into the eudiometer, renders the gas impure.

The gas must now be left to repose for at least half an hour, in order that it may attain the temperature of the surrounding air. The volume is then determined with the usual precautions, and a moistened ball of potash introduced by its attached iron wire, for the purpose of absorbing the carbonic acid formed by the explosion. If the quantity of carbonic acid is very considerable, it is necessary to remove the first ball and replace it by a second in the course of several hours. As soon as the absorption is completed the gases are likewise thoroughly dried.

It is now necessary to ascertain how much oxygen gas still remains in the eudiometer after the explosion. For this purpose hydrogen is made in a small flask from pure zinc and distilled sulphuric acid, and after all the air is expelled from the flask, it is conducted, still moist, into the eudiometer. The gas in the eudiometer is now dried by the introduction of a ball of fused chloride of calcium attached to a wire. The volume of the hydrogen is then accurately determined, and the mixture exploded by the electric spark with all the precautions already described. One-third of the volume of the gas which has disappeared is oxygen. The residual gas, still saturated with water, can now only contain nitrogen and the excess of hydrogen, and by deducting the known amount of the latter, we determine the proportion of nitrogen present.

By the preceding methods we have determined directly the quantities of oxygen, carbonic acid, and olefiant gas, and we have data for calculating with perfect precision the amount of carbonic oxide, hydrogen, light carburetted hydrogen, and nitrogen. The latter gas is deter-

mined, as we have just stated, by subtracting the known excess of hydrogen from the gas remaining after explosion.

To determine the amount of carbonic oxide, hydrogen, and light carburetted hydrogen, we employ in calculation the three quantities following, from the analysis :—

1. The quantity of combustible gases, which is obtained by subtracting the amount of nitrogen contained in the gaseous mixture in the large eudiometer.

2. The quantity of oxygen consumed in the oxydation of the combustible gases. This we obtain by subtracting the excess of oxygen, as ascertained by explosion with hydrogen, from the amount originally added.

3. The quantity of carbonic acid formed by the combustion.

The calculation depends upon the circumstance that both hydrogen and carbonic oxide require half their volume of oxygen for combustion; that one volume of light carburetted hydrogen requires two volumes of oxygen, and that carbonic oxide and light carburetted hydrogen generate carbonic acid equal in volume to themselves.

If we designate the whole volume of the combustible gases as A, the volume of the oxygen consumed as B, and the carbonic acid formed as C, and further, if we call the unknown quantities of hydrogen, light carburetted hydrogen, and carbonic oxide gas, by x, y, z, we obtain the following equations :—

$$x + y + z = \mathrm{A}$$
$$\tfrac{1}{2}\, x + 2\, y + \tfrac{1}{2}\, z = \mathrm{B}$$
$$y + z = \mathrm{C}$$

From these are deduced the following values for the unknown quantities, x, y, z.

$$x = \mathrm{A} - \mathrm{C}$$
$$y = \frac{2\ \mathrm{B} - \mathrm{A}}{3}$$
$$z = \mathrm{C} - \left(\frac{2\ \mathrm{B} - \mathrm{A}}{3}\right)$$

In the analyses of the following gases of mines, positive values are only obtained for y, but for x and z, either no values, or small numbers, sometimes positive, sometimes negative, which mutually destroy each other; in other words, the gases of mines contain neither hydrogen nor carbonic oxide. There is one striking exception, however, in which hydrogen is found.

The gases were analyzed in the manner already described, and in noting the data for calculation, the following corrections were at once made.

The volumes noted as observed, are not those actually read off from the eudiometer, but the true value of the volumes as ascertained by calibrating the tube, and correcting for the parallax of the mercury.

The heading designated "Column of Mercury above surface of that in the trough," signifies the amount that it is necessary to subtract from the column of mercury in the barometer on account of the difference of level in the inner and outer part of the eudiometer.

In the reduction of the volumes observed to 0° c. the co-efficients of dilation of air, as determined by Rudberg, are assumed as correct.

The determination of the increase of volume by the tension of aqueous vapour, is calculated from Despretz's table.

Gas from a seam of Coal 24 feet below the Bensham seam, Hebburn Colliery.

This gas is brought up in pipes to the Bensham seam, and used for lighting the underground stables. The floor of the workings of the Bensham seam was observed to rise occasionally, and eruptions of gas were attributed to the escape of that which was confined beneath. This seam was therefore tapped by bores in the Hebburn Colliery, and the gas rendered useful above for lighting the mine. All that was necessary in collection was to attach the receiver to one of the gas burners. The first sample analyzed was collected by myself, in the manner previously described, by allowing the gas to stream through a system of dry tubes.

	Volume.	Temperature.	Pressure.	Column of Mercury above that in trough, in mm.	Corrected volume at 0° C. and 1m 000 pressure.
Gas used	118·2	16·5	m. 0·7680	49·0	78·6
After absorption of $C\,O_2$ . . .	115·5	16·5	0·7686	52·2	78·0
" " $C_4\,H_4$ . .	idem	idem	idem	idem	idem
" " O	114·7	16·9	0·7686	53·2	77·3
Gas used (moist)	107·3	17·0	0·7686	330·2	42·8
After admission of O (moist) . .	306·9	17·0	0·7686	136·1	178·6
After combustion	201·5	16·8	0·7686	237·4	98·1
After absorption of $C\,O_2$ . . .	133·4	16·0	0·7717	304·5	58·8
After admission of H (dry) . .	316·9	16·2	0·7717	121·1	198·0
After combustion	80·3	16·8	0·7711	356·0	30·3

Composition in 100 Parts.

Oxygen	0·9
Nitrogen	6·7
Carbonic acid	0·7
Light carburetted hydrogen . .	91·8
	100·1

The following analyses are of the same gas collected by Mr. Easton, the proprietor of the pit, about a month afterward, by the pneumatic method.

	Volume.	Temperature, C.	Pressure.	Column of Mercury above that in trough.	Corrected volume at 0° C. and 1=00 pressure.
			m.		
Gas used (moist)	120·3	12·4	0.7602	65·6	78·7
After absorption of CO_2 . . .	117·8	12·5	0.7602	68·1	78·0
„ „ C_4H_4 . .	idem	idem	idem	idem	idem
„ „ O . . .	idem	idem	idem	idem	idem
Gas used	107·6	14·8	0·7566	305·6	44·8
Oxygen being admitted (moist) .	294·7	15·0	0·7563	120·0	174·3
After the combustion (moist) . .	185·0	15·3	0·7560	228·5	90·2
„ absorption of CO_2 . . .	113·4	15·8	0·7497	299·8	48·3
Hydrogen being admitted (dry) .	300·1	15·5	0·7532	114·9	180·7
After combustion	110·0	15·5	0·7534	303·2	44·5

II. Analysis of same Gas.

	Volume.	Temperature, C.	Pressure.	Column of Mercury above that in trough.	Corrected volume at 0° C. and 1=000 pressure.
			m.		
Gas used (moist)	96·8	13·0	0·7721	69·6	63·8
After absorption of CO_2 . . .	94·9	14·0	0·7724	72·1	63·1
Gas used (moist)	124·0	16·3	0·7521	281·9	53·4
Oxygen being admitted (moist) .	308·7	16·8	0·7517	98·7	185·7
After combustion (moist) . . .	177·9	16·0	0·7508	227·4	85·7
„ absorption of CO_2 . . .	87·7	15·7	0·7530	318·1	36·1
Hydrogen being admitted (dry) .	265·2	16·0	0·7534	141·8	153·2
After combustion (moist) . . .	128·1	16·4	0·7534	277·7	55·8

Composition in 100 Parts.

	I.	II.
Nitrogen	6·4	6·6
Carbonic acid	0·9	1·1
Light carburetted hydrogen . . .	92·7	92·3
	100·0	100·0

These analyses agree perfectly with the previous one, if we suppose that the gas collected in the dry way was contaminated with a small quantity of air, which is quite possible from its mode of collection. The oxygen present, therefore, in the first case, is obviously an impurity, and, viewed as such, the composition of the gas collected at an interval of a month is exactly the same.

Wallsend Gas.

This gas was collected from the pipe which is let down into a seam of four acres of a fiery coal at a depth of 150 fathoms. It is stated that 11,000 of hogsheads of gas per minute form the average supply obtained from this fiery seam of four acres. The gas is ignited at the orifice of the pipe above ground, and forms a large flame constantly burning, which is seen like a bonfire for miles round. The gas was collected in the dry way.

	Volume.	Temperature, C.	Pressure.	Height of Mercury above that in trough.	Corrected volume at 0° C. and 1m·000 pressure.
Gas used (moist)	102·8	15·3	m. 0·7780	63·7	68·3
After absorption of CO_2 . . .	100·8	15·0	0·7774	64·7	68·1
" " C_4H_4 . .	idem	idem	idem	idem	idem
" " O	idem	idem	idem	idem	idem
Gas used (moist)	167·4	14·9	0·7774	270·0	78·5
Oxygen being admitted (moist) .	308·4	15·0	0·7778	38·6	281·2
After combustion (moist) . . .	247·3	14·5	0·7779	192·5	134·6
After absorption of CO_2 . . .	135·3	13·1	0·7749	301·9	61·1
Hydrogen being admitted (moist)	359·8	13·8	0·7741	85·7	231·5
After combustion	145·7	14·5	0·7733	292·5	64·5

Composition in 100 Parts.

Nitrogen	6·9
Carbonic acid	0·3
Light carburetted hydrogen	92·8
	100·0

Bensham Seam, Jarrow.

This specimen was taken from the furnace return, in gas almost free from air, by emptying a bottle filled with water, and allowing the bottle to remain for some time in the gas.

	Volume.	Temperature.	Pressure.	Column of Mercury above that in trough.	Corrected volume at 0° C. and 1m·000 Bar.
Gas used (moist)	122·5	13·8	m. 0·7453	55·4	79·1
After absorption of CO_2 . . .	118·5	13·8	0·7443	59·1	77·4
" " C_4H_4 . . .	idem	idem	idem	idem	idem
" " O	118·2	14·0	0·7432	59·6	76·9
Gas used (moist)	125·7	14·1	0·7429	280·0	53·9
Oxygen being admitted (moist) .	308·8	14·4	0·7426	98·2	185·4
After combustion	190·0	14·4	0·7431	215·9	92·9
After absorption of CO_2 . . .	108·3	13·0	0·7515	297·1	47·0
Hydrogen being admitted (dry) .	282·6	13·4	0·7523	123·8	169·3
After combustion (moist) . . .	120·1	13·4	0·7523	285·6	39·1

	Volume.	Temperature.	Pressure.	Column of Mercury above that in Trough.	Corrected volume at 0° C. and 1m·000 Bar.
			m.		
Gas used (moist)	112·1	15·5	0·7499	67·9	71·0
After absorption of CO_2 & O . .	108·0	15·5	0·7493	72·8	69·2
Gas used (moist)	130·4	16·1	0·7489	276·9	56·4
Oxygen being admitted (moist) .	317·8	16·1	0·7489	91·5	193·2
After combustion (moist) . . .	194·9	16·0	0·7487	212·5	96·0
After absorption of CO_2 . . .	110·6	13·5	0·7467	296·5	47·4
Hydrogen being admitted (dry) .	294·4	13·5	0·7458	114·2	177·2
After combustion (moist) . . .	134·3	13·5	0·7457	272·7	59·0

Composition in 100 Parts.

	I.	II.
Nitrogen	14·2	13·8
Oxygen	0·6	2·5
Carbonic acid	2·1	
Light carburetted hydrogen . .	83·1	83·7
	100·0	100·0

Bensham Seam, Hebburn Pit.

This gas was collected by the pneumatic method from a small blower. The depth was 161 fathoms.

	Volume.	Temperature, C.	Pressure.	Column of Mercury above that in trough.	Corrected volume at 0° C. and 1m·000 Bar.
			m.		
Gas used (moist)	113·3	16·3	0·7632	54·4	74·3
After absorption of CO_2 . . .	109·8	16·3	0·7632	58·0	73·1
" " C_4H_4 . . .	..	..	..	..	..
" " O	..	..	..	..	..
Gas used (moist)	133·3	16·7	0·7635	304·9	55·8
Oxygen being admitted (moist) .	360·4	16·8	0·7640	85·1	225·7
After combustion (moist) . . .	243·8	16·6	0·7644	197·1	127·1
After absorption of CO_2 . . .	167·1	16·0	0·7687	270·6	78·4
Hydrogen being admitted (dry) .	402·3	16·0	0·7685	45·8	274·7
After combustion (moist) . . .	138·5	16·0	0·7685	299·8	59·5
Gas used (moist)	80·5	16·2	0·7685	86·9	50·7
After absorption of CO_2 . . .	77·6	16·2	0·7686	88·5	49·8
Gas used (moist)	130·6	16·0	0·7686	305·5	55·3
Oxygen being admitted (moist) .	342·2	16·0	0·7686	100·5	211·6
After combustion (moist) . . .	223·8	16·0	0·7687	214·0	114·4
After absorption of CO_2 . . .	145·6	14·3	0·7692	290·5	66·2
After admission of H (dry) . .	374·2	14·5	0·7690	70·2	248·3
After combustion (moist) . . .	155·8	14·8	0·7690	280·4	70·3

Composition in 100 Parts.

	I.	II.
Nitrogen	11·9	12·3
Carbonic acid	1·6	1·7
Light carburetted hydrogen	86·5	86·0
	100·0	100·0

Bensham Seam, Wallsend Pit.

This gas was collected by the pneumatic method.

	Volume.	Temperature.	Pressure.	Height of Column of Mercury above that in trough.	Corrected volume at 0° C. and 1m·000 Bar.
			m.		
Gas used (moist)	96·1	13·0	767·2	87·1	61·3
After absorption of CO_2 (dry)	93·7	13·5	767·2	89·3	60·5
" " O (dry)	93·6	13·5	767·2	89·3	60·5
Atmospheric air (moist)	306·1	14·8	764·4	145·6	176·0
Oxygen being admitted (moist)	374·1	15·2	763·8	80·5	237·6
The gas " " (moist)	403·7	15·1	763·3	49·0	268·4
After combustion (moist)	353·1	14·8	762·4	97·5	218·5
After absorption of CO_2 (dry)	322·4	15·5	760·4	126·7	193·4
Hydrogen being admitted (dry)	428·5	15·6	760·6	25·3	298·1
After combustion (moist)	282·4	16·0	760·7	165·5	155·2

Composition in 100 Parts.

Nitrogen	21·1
Carbonic acid	1·3
Light carburetted hydrogen	77·5
	99·9

Gas from the five-quarters Seam, Oakwell Gate Colliery, near Gateshead.

The seam from which this gas is taken is 53 fathoms from the surface, and 16 from the Bensham Seam. It was collected by the pneumatic method.

	Volume.	Temperature.	Pressure.	Column of Mercury above surface of that in trough.	Corrected volume at 0° C. and 1m·000 Bar.
			m.		
Gas used (moist)	86·8	12·0	0·7677	79·7	56·3
After absorption of CO_2	85·3	12·0	0·7677	81·6	56·0
" " C_4H_4	idem	..	..	..	..
" " O	..	..	..	..	..
Gas used (moist)	134·3	12·5	0·7674	302·1	58·3
Oxygen being admitted (moist)	372·4	12·8	0·7674	71·8	243·5
After combustion	240·6	12·8	0·7674	198·1	128·3
After absorption of CO_2	153·5	13·0	0·7670	283·8	70·8
Hydrogen being admitted (dry)	374·0	13·0	0·7670	71·3	248·4
After combustion (moist)	95·6	13·5	0·7670	339·7	38·2

	Volume.	Temperature.	Pressure.	Column of Mercury above surface of that in trough.	Corrected volume at 0° C. and 1m·000 Bar.
			m.		
Gas used (moist)	107·9	14·3	0·7668	59·8	71·1
After absorption of CO_2 . . .	106·0	14·6	0·7668	62·0	70·8
Gas used (moist)	131·4	14·9	0·7665	306·5	55·6
Oxygen being admitted (moist) .	346·4	15·0	0·7664	98·4	215·2
After combustion (moist) . . .	211·1	15·0	0·7662	228·5	105·1
After absorption of CO_2 . . .	119·9	14·8	0·7648	318·7	50·7
Hydrogen being admitted (dry) .	321·7	14·8	0·7648	122·5	196·0
After combustion (moist) . . .	114·6	15·0	0·7648	323·0	46·5

Composition in 100 Parts.

	I.	II.
Nitrogen	1·3	1·5
Carbonic acid	0·5	0·4
Light carburetted hydrogen .	98·2	98·1
	100·0	100·0

Jarrow Five-quarter Seam.

This gas, also derived from the same seam in geological position as the last, was collected by the pneumatic method.

	Volume.	Temperature.	Pressure.	Height of Column of Mercury over that in trough.	Corrected volume at 0° C. and 1m·000 Bar.
			m.		
Gas used (moist)	99·7	11·0	768·1	88·3	64·2
After absorption of CO_2 (dry) .	96·9	10·8	768·1	91·5	63·1
After absorption of O (dry) . .	96·9	11·5	768·0	91·2	63·1
Atmospheric air (moist) . . .	312·9	11·5	770·1	136·1	187·3
The gas being admitted (moist) .	346·0	11·9	770·1	104·3	217·3
Oxygen being admitted (moist) .	388·5	11·9	770·1	63·6	259·1
After combustion (moist) . . .	328·7	12·1	770·1	120·8	201·0
After absorption of CO_2 (dry) .	293·3	12·0	769·4	155·2	172·6
Hydrogen being admitted (dry) .	422·0	12·1	768·9	31·6	298·0
After combustion (dry) . . .	356·1	12·0	767·1	94·9	229·3

The composition of this in 100 parts, as deducted from the analysis, is,—

Nitrogen	4·9
Carbonic acid	1·7
Light carburetted hydrogen . .	93·4
	100·0

Jarrow Low Main.

The gas examined was collected from a small blower in the Low Main Seam, the place in which the late fatal explosion took place at Jarrow. The gas was collected by the pneumatic method.

	Volume.	Temperature.	Pressure.	Height of Column of Mercury over that in trough.	Corrected volume at 00 C. and 1=000 Bar.
			m.		
Gas used (moist)	107·1	12·6	764·6	72·9	69·7
After absorption of CO_2 (dry)	103·8	12·6	764·8	76·4	68·3
" " O (dry)	101·0	12·4	764·8	79·8	66·2
Atmospheric air (moist)	304·6	12·5	765·1	144·0	177·7
Oxygen being admitted (moist)	369·3	12·5	765·2	81·8	237·5
Gas admitted (moist)	397·7	12·5	765·2	54·2	266·2
After combustion (moist)	347·8	12·0	765·2	102·0	217·4
After absorption of CO_2 (dry)	317·8	12·5	766·8	131·3	193·1
After admission of hydrogen (dry)	425·6	12·7	767·2	31·1	299·4
After combustion (moist)	277·8	12·6	767·2	170·0	155·6

The composition in 100 parts, as deduced from the preceding analysis, is as follows:*—

Nitrogen	12·3
Carbonic acid	2·0
Oxygen	3·0
Light carburetted hydrogen	79·7
Hydrogen	3·0
	100·0

By tabulating the results of the previous inquiry, we find that the fire-damp of various seams and mines is composed as follows:—

Names of Mines from which the Gas was procured.	Nitrogen.	Carbonic Acid.	Oxygen.	Light Carburetted Hydrogen.	Hydrogen.
I. Hebburn Pit—small seam 24 feet below Bensham Seam	6·7	0·7	0·9	91·8	0·0
II. Same gas collected a month after	6·4	0·9	0·0	92·7	0·0
III. Same as last	6·6	1·1	0·0	92·3	0·0
Wallsend gas, from pipe above ground	6·9	0·3	0·0	92·8	0·0
Jarrow—Bensham Seam	14·2	2·1	0·6	83·1	0·0
Same gas	13·8	2·1	0·4	83·7	0·0
Hebburn Pit—Bensham Seam	11·9	1·6	0·0	86·5	0·0
Same gas	12·3	1·7	0·0	86·0	0·0
Wallsend Pit—Bensham Seam	21·1	1·3	0·0	77·5	0·0
Well-Gate Colliery, ¾ seam	1·3	0·5	0·0	98·2	0·0
Same gas	1·5	0·4	0·0	98·1	0·0
Jarrow—¾ seam	4·9	1·7	0·0	93·4	0·0
Jarrow Low Main	12·3	2·0	3·0	79·7	3·0

These analyses confirm those made by Bischoff, as far as relates to the presence of carbonic acid in the explosive gases of mines. Professor

* The presence of hydrogen in this specimen must be looked upon with suspicion until confirmed by further analysis. Unfortunately the small supply prevented the repetition of the analysis, and detection of the error.

Graham did not detect this gas in the specimens examined by him, but this was, probably, owing to the pneumatic method having been adopted in their collection. Its presence is of interest as showing that the process of decomposition is even yet going on in the coal. The nitrogen contained in these gases cannot have been derived from the decomposition of the coal; for we are ignorant of any process of decomposition which would eliminate it in an isolated form. The processes of decay and putrefaction would cause its separation as ammonia, and the action of heat would produce the same effect. The presence of nitrogen, in several cases amounting to 14 and 21 per cent., can only be explained by supposing that air has permeated the fissures of the coal, and acting upon it, has been robbed of its oxygen, partly by union with hydrogen, partly with carbon. The ready solubility of carbonic acid accounts for the small proportion in which it is mixed with the other gases. The following analyses* of two of the coals from which the gas issued will show the changes which have taken place:—

	Coal of $\frac{5}{4}$ Seam, Oakwell Gate Colliery.	Coal of Benaham Seam, Hebburn Colliery.
Carbon	85·30	86·44
Hydrogen	6·30	5·74
Nitrogen	0·28	0·41
Sulphur	0·36	0·44
Oxygen	5·55	5·67
Ashes	2·21	1·30
	100·00	100·00

Subtracting from these analyses the incombustible ingredients, they agree very well with the general formula $C_{24}H_{13}O$, deduced from the analyses of Richardson and Regnault, and render highly probable the view taken by Liebig, and expressed in the following scheme:—

3 atoms of	carburetted hydrogen	$C_3\,H_6$	$C_{36}\,H_{22}\,O_{22}$ = Wood
3 „	water	$H_3\,O_3$	$C_{12}\,H_9\,O_{21}$
9 „	carbonic acid . . .	$C_9\,O_{18}$	
		Coal . .	$C_{24}\,H_{13}\,O$

The presence of nitrogen and carbonic acid seem clearly to show that such a process is in action, and that not only does woody fibre lose carburetted hydrogen in passing into coal, but also, by a process of oxidation, carbonic acid and water. The oxygen acids present in the ashes have, doubtless, aided in the oxidation; but the complete withdrawal of oxygen from the nitrogen, which can have entered only as atmospheric air, shows clearly how powerfully the deoxidating action has been.

* The details of these analyses will be given in a 'Report to the Admiralty on the Coals of Great Britain,' by Sir H. De la Beche and myself. The analyses have been executed by Mr. Wrightson.

The explosive gas of anthracitic mines is essentially the same as that evolved from bituminous beds. I have been unable to procure any anthracitic fire damp free from air, but the following analysis of gas from Cwm Twrch colliery, though contaminated with much air, shows that there is no singularity in composition:—

	Volume.	Temperature, C.	Pressure.	Height of Column of Mercury over that in trough.	Corrected volume at 0° C. and 1m·000 Bar.
Gas used (moist)	114·0	16·0	761·4	72·1	72·8
After absorption of CO_2 (dry) .	111.4	15·8	760·6	74·7	72.2
" " O (dry) . .	97·5	15·5	749·9	89·8	60.9
Gas used (moist)	78·6	15·4	750·6	226·1	38·1
Oxygen being admitted (moist) .	156·3	15·3	751·0	148·1	87·3
After combustion (moist) . . .	130·0	15·5	751·0	174·7	69·3
" absorption of CO_2 (dry) .	113·9	15·3	751·2	191·0	60·4
Hydrogen being admitted (dry) .	273·2	14·6	752·3	32·2	187·6
After combustion (moist) . . .	163·8	14·4	752·3	140·7	93·3

Composition in 100 *Parts.*

Nitrogen	63·8
Carbonic acid	0·8
Oxygen	15·5
Light carburetted hydrogen . . .	19·3
	99·4

It is possible that the continued slow action of heat may effect the transformation of woody fibre or of a bituminous coal into anthracitic coal, but the gases evolved must, in such cases, be more complex. Whether or not nature employs the action of a slow heat in the preparation of anthracitic coal it is difficult to say; but we certainly can obtain a very perfect anthracite by such means. An anthracite quite similar to native anthracite in appearance was obtained by a very gradual and prolonged coking of the bituminous furnace coal of Alfreton, and is deposited in this Museum.

Doubtless, in this transformation by heat, various hydrocarbons are expelled. In the vicinity of Cupar, in Fifeshire, there is a basaltic dyke, which has passed through the coal measures. When a fragment of this basalt is broken the freshly-exposed surface is quite moist with naphtha, which quickly evaporates; it cannot be doubted that this naphtha must have been formed by the action of heat upon the coal. We may not yet be able to explain all the transformations of woody fibre into coal, but their nature is sufficiently indicated by the composition of the gases.

It may not be out of place to consider the manner in which the ancient

vegetation, now constituting our coal beds, became destroyed in such a way as not to be transformed into the usual gaseous constituents of decaying matter, especially as no definite ideas seem to be entertained on this subject. We know of instances, in modern times, of forests buried in peat bogs, where the character of the trees proves that their destruction is comparatively recent. Sir Humphry Davy endeavoured to explain their entombment by supposing that the axe was used too indiscriminately, and that the felling of the exterior trees left the interior ones exposed, and too feeble to resist the weather. This is certainly not a sufficient explanation, as we observe no such catastrophe following similar errors in judgment at the present time.

A curious case is pointed out by Mr. Binney, in Lancashire, where there is evidence of a bank having been thrown up by the sea at the margin of one of those forests antecedent to its destruction. The effect of a bank thrown up at the margin of a forest must be to stop the natural drainage of a country, and throw it into the state of a marsh or bog. The roots of trees require an abundant supply of oxygen, which is an essential constituent of the sap, and exists in larger proportion than in common air in the spiral vessels. The marshy state of the land formed a barrier to the ingress of air to the soil, and, consequently, to the roots. The leaves which fell, the broken branches which strewed the ground, were placed in favourable conditions to decay. They could not do so, however, by the mere action of the air, which was, to a great extent, precluded, and they therefore acted upon the peroxides of iron in the soil, and robbed it of its oxygen, as we know organic matter readily does. All the iron in the soil was now reduced to protoxide, and a complete barrier to the entrance of oxygen to the roots was effected; for as soon as any was absorbed by the soil it must have been appropriated by this lower oxide, which, on elevation to the peroxide, again yielded it to the dead organic matter. The trees were now in a condition in which they could not possibly subsist; for deprived of an essential condition to their sustenance; surrounded by a matter which is positively poisonous to vegetable life, it is easy to conceive that whole forests were destroyed. This is not an ideal order of events even in the case of the vegetation constituting coal; for analysis shows the underclay of the coals, the soil in which they are supposed to have grown, to be so charged with protoxide of iron as to prevent the possibility of a plant growing; and any stagnation to the water, sufficient to cause reduction, would produce the same effect to the coal vegetation as to that employed by way of illustration in the bogs and marshes of the present time. The following is an analysis of an underclay made by my pupil, Mr. Frankland:—

Silica	61·91
Alumina	21·73
Protoxide of iron	4·73
Lime	0·09
Magnesia	0·59
Potash	3·16
Soda	0·25
Chloride of sodium	0·08
Organic matter	0·70
Water	6·73
	99·97

If such a course of events happened, and its probability is strengthened by geological considerations, there is no difficulty in accounting for the destruction of the ancient vegetation; the absence of the air would cause the preservation of woody fibre, which could only undergo the putrefactive mouldering which gives rise to wood coal. Being entombed in this state under considerable pressure, and at a temperature higher, at all events, than the surrounding air, its further decomposition and the elimination of carburetted hydrogen, carbonic acid, and water, would proceed just as we find it in progress at the present day.

Museum of Economic Geology,
1st June, 1846.

Note on the Gogofau, or Ogofau, Mine, near Pumpsant, Caermarthenshire. By Warington W. Smyth, M.A., Cambridge, F.G.S., Mining Geologist to the Geological Survey of the United Kingdom.

This mine, which has so long attracted the attention of the antiquary, is situated on the left bank of the Cothy, forming part of the grounds of Dolau Cothi, the residence of Mr. Johnes, to whom the survey is indebted for much valuable aid during its progress in that part of Wales. He informs us, that the traditions of the country point to the Romans as the originators of these works, and that they were carried on in search for gold. The remains of Roman pottery, ornaments, and a bath afford reason, Mr. Johnes considers, for presuming that there was a Roman station near this spot, connected with the mines. Several gold ornaments have been discovered, and a beautifully wrought golden necklace is now in the possession of Mrs. Johnes. The name of the parish, Conwill Gaio, tends also, Mr. Johnes remarks, to the conclusion, that the Romans occupied this ground, provided the interpretation given to it be correct, for Conwill Gaio is supposed to signify "the advanced post of Caius." The name of Melin-y-milwyr, *Anglicè*, "The Soldiers' Mill," is given to the remains of a pond, supposed to have supplied the works with water, brought for a distance of eight or ten miles, allowing for curvatures, along the sides of the hills, from a place in the Cothy called Porth uffern, or Hell's Gate. This old water-course can still be traced, at intervals, for the distance. The allusion to soldiers is considered to have reference to the Roman soldiers who may have been employed in the works.

The Romans were, of all the nations of antiquity, the most successful in bringing their colonies to a high state of prosperity, which, considering the military nature of their colonization, we should hardly be prepared to expect; and we find that their settlements in the North, South, East, and West, still remained vigorous, whilst internal corruption destroyed their great centre; and that they only fell when their protecting troops had been recalled, and they were left a defenceless prey to the barbarian swarms which formed so striking a feature of those times.

Among the various ways adopted by the Romans for augmenting the commerce of their settlements, there are two, of which the traces still remain; the improvement in communication by the laying out of good roads, and the development of the mineral wealth of a country by

mining; and since authenticated remains of the latter are very rare in this country, it becomes important to examine with care whatever is attributed to the agency of that great people, and to compare it with their known works in other parts of the world.

It has been a matter of surprise with those who visited the Ogofau that iron pyrites was the only ore visible, and that large heaps of apparently pure quartz, carefully broken to the size of a common nut, were alone found. The geological survey discovered, however, a specimen of free gold in the quartz of one of the lodes, and thus corroborated the evidence which tended to prove that the mines were worked for gold.

The majority of the workings extending to a considerable depth for some acres over the side of the hill, are *open to the day*, or worked, as usual, in the early days of mining, like a quarry; and the rock through which the lodes run, a portion of the lower Silurian rocks, is in many places exposed, and exhibits beds much contorted and broken, though having a general tendency to dip northward. Here and there a sort of cave has been opened on some of the quartz veins, and in some cases has been pushed on as a gallery, of the dimensions of the larger levels of the present day, viz., six to seven feet high, and five or six feet wide, and among these, two of the most remarkable (represented in plate 8) are kept clear by Mr. Johnes, and being easily accessible, allow of close examination. The upper surface of the hill is at this, the south-western extremity of the workings, deeply marked by a trench running N.E. and S.W. similar to the excavations technically called *open casts*, where the upper portions of the lodes were in very early times worked away; and when it was afterwards found disadvantageous to pursue the lode in this manner, a more energetic and experienced mind must have suggested the plan of driving adit levels from the north face of the hill through the barren rock in order to *cut* the lode, at a greater depth than it could otherwise be reached; and the perseverance exhibited in driving 170 feet through the slate in each of the levels in question, was no doubt based on a sufficient knowledge of the continuous nature of a mineral lode.

The upper level communicates with the trench on the surface of a *rise* on the lode, and with the lower level by a passage of some few feet in length, through which it is barely possible to creep, and then by workings from which a considerable quantity of matter has been removed. The miners could hardly have selected a spot where they could with greater reason hope for success, since several lodes with different inclinations have crossed each other in this small space; and it is evident that farther excavations were carried on at some depth, farther to the N. E., for the breaking in of the rock above has given rise to funnel-shaped hollows of considerable size on the surface.

The veins or lodes of quartz vary many degrees in their line of direction, and dip at angles of from 28° to 80°,—some to the S. E., others to the N. W.; and their width varies from an inch to a foot. The quartz is chiefly massive, and not very transparent; it frequently contains iron pyrites of the ordinary variety, crystallizing in cubes, and a few specks of galena may be detected in some parts.

The extended open-cast workings to the westward* appear to have been carried on through and around an intersection of quartz veins, similar in character, though more extensive and metalliferous than the above; but as the ramifications recede from the centre, the useful contents must have diminished in quantity.

We have carefully examined the quartz matrix from all the old workings, but the above-mentioned minute particle of gold remains the only specimen of the precious metal which has rewarded our search.

At an inconsiderable distance from the old workings lies a large block of sandstone, approximating in form to a four-sided prism, the faces of which are indented by rudely circular and elliptical hollows of small depth, evidently caused by artificial attrition. It appears highly probable that this stone was employed as a mortar for the purpose of breaking up or *bucking* the ore, a process still in use in cases where it is important to pick out valuable portions by hand. The traditions of the country, however, refer its indentations to a much more marvellous cause, connected with the five saints from whom the adjacent village, Llanpumpsant, derives its name. †

* Among the numerous irregular caves at the western end of Ogofau, is one which has derived the name of *Ffynnon Gwenno* (the well of Gwenno), from the following tradition kindly given to us by Mr. Johnes. The water which still occupies its lower part, was, in days of yore, reputed to possess medicinal qualities, which attracted numerous bathers from the surrounding district. Among these, a fair maid, named Gwenllian, or, for brevity, Gwenno, was induced, on an unfortunate day, to attempt to explore the recesses of the cavern beyond a frowning rock, which had always been the prescribed limit to the progress of the bathers. She passed beneath it, and was no more seen; she had been seized by some superhuman power, as a warning to others not to invade those mysterious penetralia; and still, on stormy nights, the spirit of Gwenllian is seen to hover over a lofty crag which rises near the entrance of the now deserted cave, and bears the name of *Cloch ty Gwenno*, or Gwenno's steeple.

† "Five juvenile saints, on their pilgrimage to the celebrated shrine of St. David, emaciated with hunger, and exhausted with fatigue, here reclined themselves to rest, and reposed their weary heads on this ponderous pillow; their eyes were soon closed by the powerful hand of sleep, and they were no longer able to resist, by the force of prayer, the artifices of their foes. The skies were suddenly obscured with clouds, the thunder rolled, the lightning flashed, and the rain fell in overwhelming torrents. The storm increased in vehemence, all Nature became chilled with cold, and even Piety and Charity felt its effects. The drops of rain were soon congealed into enormous hailstones, which, by the force of the wind, were driven with so much violence on the heads of the weary pilgrims, as to affix them to their pillow, and the vestiges they left are still discernible. Being borne away in triumph by the malignant sorcerer who inhabits the hollows of these hills, they were concealed in the innermost recesses of his cavern, where they are destined to remain

In considering the proofs of the Roman origin of these works, one of the most remarkable points is the large size of the levels, whilst we know that the galleries of mines for some centuries previous to the general application of gunpowder in blasting, were made so small as to render it very painful to walk through them for an hour or two. Examples of this are frequent in the older mines in Cornwall, and still more so on the continent of Europe; nor till we go back to the time of the Romans, have we anything with which we can compare the *Ogofau*; but in the extraordinary hill called *Csetate*, or fortress, at Verespatak, in Transylvania, the grand arches and roomy tunnels wrought in hard sandstone and porphyry by that enterprising people, throw into the shade the puny works of their followers, and prove that the art of extracting gold from quartz,—even where invisible to the naked eye,—was then understood. This place was, no doubt, an important spot in Dacia Ulterior; and the ornaments and implements of massive gold frequently found in the neighbourhood, and mostly deposited in the Imperial Cabinet at Vienna, bear witness to the abundance in which this precious metal was obtained.

If we examine Pliny for the state of knowledge on this subject among the Romans, we find that gold was obtained by three processes:—first, washing the sands of certain rivers; secondly, following the lode by shafts and levels (*puteis et cuniculis*), whilst the earth is supported where necessary by props or pillars of wood; thirdly, by excavating hollows

asleep, bound in the irrefragable chains of enchantment until that happy period shall arrive when the diocese shall be blessed with a pious bishop; for, when that happens, no doubt Merlin himself, the enemy of malignant sorcerers, will be disenchanted, and he will come and restore to liberty the dormant saints, when they will immediately engage in the patriotic work of reforming the Welsh."—*From the English Works of the late Rev. Eleazar Williams.*

of larger magnitude, supported for a time by arches of rock, which are afterwards gradually removed to allow the whole superincumbent mass to break in. The ore is broken, washed, burned, ground to powder, and pounded with pestles (*quod effossum est, tunditur, lavatur, uritur, molitur in farinam, ac pilis cuditur*). In Transylvania we may see to this day the results of the two latter processes.

A sentence from Cicero has often been quoted to prove that the Romans imagined there was no silver in Britain; but Tacitus, in his 'Life of Agricola,' expressly states the occurrence both of gold and silver, "*fert Britannia aurum et argentum et alia metalla, pretium victoriæ.*" Whence, knowing that the method of extracting finely impregnated gold was practised by them, and that this metal was recorded as a produce of Britain, we need only to recollect that the flourishing time of Dacia as a colony was under Trajan, and therefore long before the legions were recalled from this island, to support, on strong grounds of probability, the assertion that the *Ogofau* were Roman gold mines; and in order to dismiss all doubt on the subject, we have only to add the evidence which Mr. Johnes has deduced from the various antiquities found in the vale of the Cothy, from which it is clear that there existed at this spot a station of some importance.

An Account of the Mining Academies of Saxony and Hungary. By WARINGTON W. SMYTH, M.A., Cambridge, Mining Geologist to the Geological Survey of the United Kingdom.

AMONG the various applications of geology to the useful purposes of life, the art of mining most directly needs the application of that science, and requires, for the successful furtherance of its views, the most extended acquaintance with the geological facts observed at different times, and in different places.

Every thinking miner must indeed, in a certain sense, though perhaps in a very confined sphere, become a geologist; little as the practical coal-viewer or mining agent may be prepared to receive the title:—and he bases his operations, whether relating to the discovery of new mineral treasures, or to the prosecution of those already found, on rules which the experience of years has taught him to lay down; and in proportion to the strength of his judgment, the retentiveness of his memory, and the opportunities of seeing and testing which have been afforded him, will he be likely to carry out advantageously the work on which he is engaged.

Looking at the class of men who, in this kingdom, are intrusted with the direction of collieries and mines, we find them, in general, characterised by a remarkable degree of energy and intelligence; and yet it cannot be denied that, independently of the losses entailed by the uncertainty of mineral veins, large sums are yearly squandered on ill-judged, and, sometimes, even absurd speculations, which a greater amount of experience, on the part of the proposer, would have taught him to modify or abandon. We cannot be surprised to hear of similar failures, when we consider, first, the comparatively short time over which a single man can extend his experiences; secondly, the great amount of phenomena which must be observed and compared to form a groundwork for practical geology; and, thirdly, the numerous branches of other arts and sciences, some of which should properly precede its study, whilst others, immediately connected with the duties of the mining agent, intervene to distract his attention, and render it difficult for him to attain a great degree of proficiency in any one particular subject.

On the continent of Europe several academies have been founded with the desirable object of supplying to miners a knowledge of geology, and the kindred sciences, and of establishing a storehouse of facts and experience, whence they should be enabled to reap the harvest sown by

those who have gone before them, and should set forward on their own career provided with such a stock of knowledge as to obviate the necessity of passing a great portion of their lives in the useless repetition of that which has been done before; and with the view of affording them a facility, by beginning where others have ended,—to form new links in the chain of improvement, and thus to carry out the process by which alone, in every pursuit, we can hope to approach perfection.

To argue at length for the advantages of such a system would be here out of place; no man will deny the justice of the observation of the Roman poet—

> "Ego nec studium sine divite venâ,
> Nec rude quid possit video ingenium."

And a suitable direction of the mind, and early exercised acquaintance with established principles, is surely no less necessary to the successful cultivation of the useful arts, than to the ornamental branch of literature.

The most remarkable of these mining colleges are those of Freiberg, in Saxony, and Schemnitz, in Hungary, because both situated in the centre of important mining and metallurgical operations, and therefore combining the advantages of general scientific instruction with the practical application of the art. As no account, however, of their plan and working has been laid before the public since the days when the name of the first-mentioned academy resounded throughout Europe, in connexion with that of its celebrated Professor, Werner, I believe a short description will prove interesting to the miner as well as the metallurgist and mine-adventurer; and since I had the opportunity of residing at each for some months in the years 1840 and 1842, and of hearing certain courses of lectures, as well as of examining the works of the surrounding districts, the information will apply nearly to the present date.

The want of an academy for educating the miners of Saxony was made apparent by the number of young men who flocked to Freiberg as pupils of Dr. Henckel, and in his house heard lectures on all the necessary subjects; whilst in the neighbourhood they were provided with the means of gaining practical experience. On his death, in 1744, students still visited the town; and at length, in 1765, a mining school was founded by Prince Xaver, during the minority of the King, which very soon, under the care of Werner, who was appointed inspector in 1775, attained great celebrity. His perfect acquaintance with the sciences on which he lectured, his activity of mind, and his excellent manner of teaching, caused his class-rooms to be frequented by strangers from all quarters. He every year read lectures on the art of mining, mineralogy, and geology, as well as on iron smelting, fossil remains, mineralogical literature, geography, &c.

These subjects have, since his time, been so amplified as to afford sufficient occupation to several Professors; and the manner in which they were distributed in 1840 was as follows:—

General Chemistry Technical Chemistry Metallurgy	Professor Lampadius. In 1844, Plattner.
Mineralogy and Mineralogical Exercises	Professor Breithaupt.
Geology, in two courses Crystallography	Professor Naumann, Senior. In 1844, Cotta.
Physics (Natural Philosophy) Palæontology	Professor Reich.
Pure Mathematics Higher Mathematics	Professor Naumann, Junior.
Mining Jurisprudence and Correspondence	Professor Lehmann.
Analytical Preparation Analytical Chemistry	Professor Kersten.
Applied Mathematics Mining Machinery General Surveying and Practical Geometry	Professor Weisbach.
Art of Mining	Professor Gätzschmann.
Surveying	Surveyor Leschner.
Drawing, in three divisions Architecture	Mr. Heuchler.
Assaying of Metals	Mr. Klemm.
French Language	Mr. Munde.

The institution is placed under the immediate control of the upper board of mines (*Oberbergamt*); the Professors, although forming no regular senate, meet on occasion in conference, where the members of the above board also sometimes take a part. The superintendence of the discipline is intrusted specially to one Professor.

Candidates for admission must produce certificates of healthy constitution, good character, and tolerable proficiency in the usual subjects of school education, and in mathematics. The testimonials are presented between January and June; and the Oberbergamt decides upon the candidates who may present themselves for the examination, which takes place in August. Those who are supported by the government have the advantage of attending the lectures gratuitously, and receive certain *stipendia* or scholarships: they are divided into two classes; the first, called the *Beneficiaten*, pass through a course of four years, and become candidates for the royal service: the other is composed of those who enter for places not requiring more than one or two years of study, or who are unable to enter as regular pupils in consequence of a want of vacancies in the corps. Independently of these, are Saxons, who pay their own expenses; and foreigners. Some of the academists, finally, go to the University of Leipzig to study jurisprudence, which is necessary for those who are to be officers in the various mining towns of Saxony. Another part, who have distinguished themselves for intelli-

gence and industry, are sent to travel at the expense of the government, or to visit foreign universities.

Saxons, in good circumstances, and foreigners can attend the academy on production of certificates of good character, and of their stay being duly authorized; they are expected, however, to pay for the courses of lectures as follows:—

General Chemistry, Analytical Chemistry, Mineralogy, the Higher Mathematics, and Machinery, each . . .	30 dollars*	per annum.
Geology, Physics, Applied Mathematics, Pure Mathematics, Metallurgy, Technical Chemistry, Architecture	20 ,,	,,
Art of Mining (two parts), Elementary Mineralogy, Mining Jurisprudence & Correspondence, Theoretical Surveying	15 ,,	,,
Practical Surveying, Assaying, and Drawing, according to circumstances.		

The students of this class are entirely free from the superintendence of the officers of the academy, and only attend the examinations if they require certificates: their number is usually about twenty, of whom three or four are officers of the Russian Mining Engineers sent by their government to reap the advantages of extended experience, whilst others are from Spain, Brazil, the smaller German States, &c.

The course of lectures opens on the first Monday in October, and ends the last Saturday in July; the two vacation months, August and September, being very useful, as giving the opportunity of making excursions with a view to mining and metallurgical observation.

The subjects are taught as in our own Universities, by lectures illustrated by figures on the black board, by experiments and by the inspection of specimens, according to the nature of the case. One day in the week (Monday) is left without lectures to enable the students to visit the works, or take part in the operations.

The ordinary pupils are expected to keep a fair copy of their notes, and are examined at least every month as well as at the close of the annual course of lectures, and are classified and rewarded according to the result.

On the expiration of the second year, the student determines whether he will attach himself more particularly to the mining or the metallurgical departments; and then pursues a course of study more especially adapted to his end. In the fourth year, practical exercises in both branches form the main feature of the course of education.

The Academic or Mining School, an establishment subordinate to the above, is intended partly to educate youths of a lower class for the situations of under-managers and viewers,—partly as a preparatory step to the Academy. The number of scholars is restricted to 40, and they are instructed in arithmetic, geometry, the art of mining, elementary

* The Saxon dollar is equal to 3*s.* sterling.

mineralogy, German grammar, and drawing, the whole course being arranged with a view to the combination of practice with a correct knowledge of principles.

A handsome building, in the centre of the town, has been erected for the use of the academy; it contains several lecture-rooms, an excellent library, to which the students are liberally admitted: a room appropriated to mining and mechanical models, and extensive and well-arranged collections of mineralogical and geological specimens.

The advantages which Freiberg possesses for practical instruction are perhaps not surpassed by any mining town in the world, seated as it is upon the metalliferous gneiss, pierced by dykes of porphyry, it is within a walk of an extraordinary variety of geological formations. On the north-west we pass over the mica slate, famous for the remarkable mines of Braunsdorf, succeeded by clay slates and conglomerates of the so-called transition class, and by the singular coal field of Haynichen. Farther west, we may visit the coal and rich iron ores of Zevickau. On the south we reach the wild crest of the Ore-mountains, where are situated the curious tin mines of Altenberg and Zinnwald; whilst on the east, we may roam through the lovely valley of Thorandt, and investigate the relations of the coal measures, the new red sandstone, the green sand, and chalk marl, with the intrusive masses of porphyry and syenite.

The metalliferous veins, exhibiting very distinct characters, may be classed in several groups, and present every species of relation one to the other: whilst in a circle round the town, with a radius of about three miles, they give occasion to the working of nearly 100 mines, where about 200 shafts, 71,000 fathoms of adit or water gallery, and about 250,000 fathoms of level or gallery, exhibit every species of timbering and masonry as used in mining. In the neighbouring valley of the Mulde, the ores are daily roasted and smelted in twenty or thirty furnaces of various construction, and the beautiful process of amalgamation is always to be seen in action.

The Academy of Schemnitz was founded during the reign of the Empress Maria Theresa, about the year 1760, for the purpose of educating officers to superintend the mining and smelting works throughout the whole of the Austrian dominions. The extent of the provinces composing the monarchy, and the low state of education in the more distant portions, made it very necessary to place under the direction of well-instructed men the management of departments so various as metalliferous mines, salt works, collieries, iron works, smelting furnaces, and forests, all of which are in some places in the hands of the Crown. The number of students has of late years considerably increased, and comprises not only those who seek for government employment, but also

many who are sent by individuals, or by mining companies to pass through the whole routine of study, or to attend only some particular courses, according to the nature of the operations which it is intended they should conduct.

Independently of political motives, which influenced the choice, Schemnitz offers great advantages for the site of a mining college. The mines adjacent to the town and distributed through the surrounding district, produce in large quantity ores of gold, silver, copper, lead, antimony, and iron, and numerous smelting works are supplied with fuel by the thick forests of oak, pine, and beech which clothe the hills. A great amount of machinery is set in motion by water carefully collected into reservoirs, and applied either to raise water and material from the shafts, or to effect the dressing of the ores; whilst the deep water-galleries, or adits, carried for miles under a lofty mountain ridge, stand pre-eminent for boldness of project and skill in execution.

The institution has been endowed with great liberality; for not only are the professors paid by the government, but such a sum is yearly granted for the expenses of the well-ordered laboratory, and for other experimental purposes, that the students obtain gratuitously an excellent education. To obtain admission, subjects of the Emperor must be able to produce certificates of having passed good examinations at their schools, and also a recommendation from one of the *Hofräthe* or Aulic councillors, whilst the same advantages are open to foreigners provided with a suitable introduction through the ambassador, or some known person in their own government.

The system of education must be followed out equally by all during the first year, after which a certain number who are allowed to pass aside to the *Forstwesen*, or forest department, are freed from a great portion of the after studies, whilst it is left to the choice of the rest to pursue voluntarily that branch in addition to the regular routine.

The subjects are divided as follows:—

First Year.

1st half. Elementary Mathematics, consisting of Geometry and Algebra, Plane and Spherical Trigonometry, Conic Sections.
Plan-drawing.

2nd half. Natural Philosophy (*Physik*) and Mechanics.
Descriptive Geometry and Stereometric Drawing.
Crystallography.

Second Year.

1st half. Chemistry.
Mineralogy.

2nd half. Metallurgy (*Hüttenkunde*).
Geognosy.

The Foresters' course is botany, practical geometry, &c.

Third Year.

1st half.	Subterranean Surveying (*Markscheidekunst*).
	Machinery and Drawing.
	Double Book-keeping.
	Botanical Abstract (on timber, &c.).
2nd half.	Art of Mining (*Bergbaukunde*).
	Dressing of Ores (*Aufbereitung*).
	Architecture, or General Building.

The Foresters are exercised in valuing standing timber, &c.

Fourth Year.

Practical exercises (*Verwendung*)	Surveying, common and subterranean,	4 months.
	Mining	1 „
	Dressing and washing of Ores . . .	1 „
	Smelting-furnaces	2 „

During the third year, the young men are required on one day in every week to go through a portion of some mine, to examine minutely every particular, and to hand in a written report upon it to their professor. A few of them even take a piece of work on bargain which assists to pay their expenses, whilst it gives them a practical acquaintance with sinking and driving.

The half-yearly examinations are conducted (notwithstanding that which some travellers may have stated to the contrary) with great strictness, and quite openly; and according to their result, the students are divided into those who gain preference (*Vorzug*), 1st class and 2nd class; those who have the misfortune of being placed in the latter (*ein zweier Kriegen*) being obliged to undergo a second trial. The *Oberst-kammergraf*, or supreme count of all the works in the district of Lower Hungary, also directs the academy, and in conjunction with the professors assists on these occasions. The questions are written on small slips of paper, and two or three of them are taken up at hazard by each in turn as he is called upon in alphabetical order, and are answered *vivâ voce*. The most successful candidates receive as a reward a species of exhibition, sufficient to defray a great portion of their expenses, whilst those who have more than twice been returned in the second class, must relinquish all claim to government employ.

In 1843 the number of students was between three and four hundred, and the Professors :—

Physics and Mathematics	Count Nyary.
Chemistry and Metallurgy	Dr. Bachmann.
Mineralogy and Geology	Mr. Petko.
Botany, and Management of Forests . .	Bergrath Feistmantel.
Art of Mining	Mr. Landerer.
Subterranean Surveying	Surveyor Marschan.
Book-keeping	Bergrath Reuth.
Machinery	Mr. Adriany.
Building and Plan-drawing	Mr. Hönig.

When the practical course has been brought to a conclusion, the passed students are draughted off to different places, and into the various branches, to serve for four, six, or even more years of probation upon a small pay, as *Praktikants*, after which, as vacancies occur, they receive the appointments for which they have been preparing.

The lectures are delivered in German, the language of the majority of the hearers, who come from Austria, Carinthia, Styria, Tyrol, and Bohemia. A tolerable library of works on technical subjects is open on appointed days, and books may be borrowed on certain conditions. The usual expenditure of the students is but small, varying from 20*l.* to 60*l.* a-year; the underground mining suit is their usual dress, though a neat uniform is worn on great occasions; a remarkable degree of harmony and good feeling prevails amongst them, and the duels so common in German universities, are here unknown.

In looking at the system pursued at the above institutions, we find at both of them a prominent defect tending to impair the usefulness of the class of men which they produce, viz., that the time is so short in which the scholars are expected to pay attention to such a multitude of subjects, that it is impossible they can acquire all of them soundly and practically; and although an excellent foundation may have been laid, it must be left entirely to after years to rear up the superstructure, when amid the pressure of business, and other cares and pursuits, there is only a small per-centage of men who feel an inclination to return to a system of study. The mode of partially obviating this evil, would be to separate more decidedly the departments of the mine and the smelting furnace; for although a portion of the earlier studies is necessary as a preparatory course for both, most of what follows cannot be obtained but at a great expenditure of time and labour; and in the ordinary routine it is as foreign to the business of the metallurgist to construct the timbering of a shaft, as to that of the miner to build a blast furnace. There are some cases, it is true, where works are to be conducted in an uncivilized country, when such an extended knowledge must be highly desirable; but for these a fuller course of preparation is clearly necessary.

To Freiberg this remark is not so applicable as to Schemnitz, since in the former the two classes are kept more distinct; and it is probably to this source that we may trace the improvements,—more particularly in metallurgy, which emanate from the Saxon Academy. In Austria it has been too common to pass men from one department to the other, as if skill in the one point must necessarily indicate a good acquaintance with another; upon the same principle which, ere now, has elevated a good oarsman on the Golden Horn from his humble *cayeek* to the command of an army. On the other hand, I cannot but bear witness that the

pupils of the Hungarian Academy, when full scope is given to them in the department which they have chiefly pursued, yield to none in the science and practical skill which they bring to bear on their object, as evinced particularly in some of their silver furnaces, in the water-pressure engines of Mr. Adriany, and the improved dressing works lately erected on a large scale by Mr. Rittengen, under the direction of the Oberstkammergraf von Svaiczer.

The nature of the metalliferous deposits in the two mining districts is so different, that it becomes difficult to institute a comparison between operations carried on necessarily in a very different manner to suit the character of the ground; and only so much is certain, that the system of each place is that best calculated to work to advantage its own lodes under their peculiar circumstances. At Freiberg we have a slightly undulated surface, hard gneiss rock, and mineral veins from two to six feet in width; so that in the mode of working, the small necessity for timber, and, in fact, in everything but the raising of water and of "stuff," we find there a perfect prototype of our own Cornish mines. At Schemnitz, on the contrary, the surface is roughly diversified with hill and dale, whilst gigantic lodes, of fifty to two hundred feet wide, sometimes forming with their decomposed felspar a mass of yielding clay, course along a ridge of greenstone porphyry, often softened by decomposition, and present difficulties to the miner which those alone can appreciate who have seen the driving of tunnels, or even small galleries, through such material. Shafts can rarely be sunk in the lodes, but are put down vertically on the hanging side; the common method of working out the contents cannot, from the great width, be adhered to, whilst the crushing softness of the filling substance demands unusual resources in walling and timbering.

Yet the scientific character of the Austrian miner has sunk below its former position, and below that which it ought from the above-named educational advantages to attain; and the cause, invisible to most on the spot, is evident to those who have examined works of a similar nature in other countries. A grave error has been committed in omitting the pursuit of science for that of practical art alone, and the consequent exclusion of the knowledge of advances made in other districts has led to their own state of backwardness. The varied circumstances of mineral deposit and other geological features occurring throughout the empire remain undescribed, and unreduced to their proper bearing, and the Schemnitz student generally passes to his distant charge, prepared only to conduct the works of the particular district around his academy, and expecting to see in other places a recurrence of the same phenomena. The very object of such an institution, to fit the miner by a general review of phenomena observed, and processes used, in

various localities, to adopt what is most suitable to the particular locality in which he will be engaged,—is lost sight of, and he is left with the one-sided knowledge and attendant prejudices which in isolated mining countries have ever obstructed the way to improvement.

The little regard that has been paid to the advance of an important branch is evinced by the fact, that in 1841, the then Professor of Geology delivered as lectures to the students the unaltered notes he had made, nearly half a century ago, from the instructions of Werner! and that I have heard some of the first of his pupils revive the ancient dreams of the "plastic virtue" of nature in regard to fossils, and doubt the existence of a regular order of stratified deposits, because they had seen nothing of the kind immediately around them.

The course of mining education fails, therefore, in one of its most important features, the inculcation of the general principles and the practical application of geology; and it need excite no surprise that serious blunders should often be committed, even in a country where such errors might be checked by the existence of an institution like the above, and, as too frequently happens nearer home, that coal should be absurdly sought in non-carboniferous geological formations, where a few black shales attract the attention of the ignorant speculator.

It has been for some time expected that a complete change will be made in the Schemnitz Academy, and some are of opinion, that the proposed end would be better attained if the preparatory studies were made in Vienna, and the observation and practice of the processes were left to be followed out in the mining district. There can be no doubt that both science and art must languish, if secluded from the general advance of other lands; and that if the cultivation of the former be forwarded in the stirring tide of full communication with the world, a valuable assistance will be conferred on those branches of the latter which are confined by nature to the bleak hill-side or remote mountain glen.

A Notice of the Mining Establishment of France. Taken from the 'Compte-Rendu des Travaux des Ingénieurs des Mines,' a document published annually, and presented to the two Chambers, in accordance with a law of the 23d April, 1833; and from the 'Annales des Mines.'

The French Corps des Mines was established by an order of Council of the 21st of March, 1781, and the 19th of March, 1783, and reorganized on the 13th Messidor, An II., and the 30th Vindémiaire, An IV. Other regulations were made in 1810, 1811, 1813, 1816, 1823, 1824, 1828, and 1831.

The mining engineers are directed to examine France, both as regards its geological structure and a knowledge of its mineral wealth.

To guide the labours of those engaged in mines or in the search for useful mineral substances.

To prepare instructions for the concession of those mines or metallurgical establishments for which the King issues ordonnances.

To indicate, from the knowledge which they have acquired of the mode of occurrence of mineral veins in a country, the limits which should be assigned to concessions, and the kind and direction of the chief works by which the mines are to be carried on.

To watch over, by frequent visits to mines and subterranean quarries, the preservation of the surface and buildings, the solidity of the works, and the safety of the mines. To afford to those in charge of the works such positive instructions, and to the authorities such advice, as may prevent accidents.

To examine into the causes which limit, or tend to limit, the working of mines; and to point out the means to be employed to prevent their continuance.

To estimate, in order to determine the royalties due to the state, the superficial extent of mines, as well as the quantity, quality, and value of their produce.

To direct the domanial and communal mines, as well as the turbaries belonging to the communes and public establishments.

To prepare regulations, in order that an uniform system of management may obtain in the same turbary district, and to arrange a general plan of drainage.

To assure themselves, by exact experiments, of the solidity of the apparatus in which steam is generated, either for motive power or for

heating purposes; to propose the conditions under which it be legalized in establishments; and, on account of the public safety, to watch over the strict observance of these conditions.

To give to commissions charged with the preparatory examinations of projected roads, canals, railways, &c., the necessary information respecting the nature and condition of the ground, the importance of the outlets which these intended improvements are calculated to afford to mines and to metallurgical and other mineral establishments.

To examine, for the public benefit, and for the security of commercial transactions, the regulations of the companies forming either for the raising or subsequent treatment of mineral substances.

To make known to the higher authorities, and the tribunals, any infractions of the laws regarding mines and metallurgical and other similar establishments.

Finally, they are charged with instructing the *élèves ingénieurs* in the theory and practice of their art, and with forming effective *maîtres mineurs* and directors of establishments.

Thus, the mining engineers are not alone appointed for the purpose of scientific investigations; they are chiefly the advisers of the *Administration des Mines* on a variety of subjects which their studies and their special knowledge enable them perfectly to comprehend; and it is through them that the "Administration" is enabled to exercise the needful surveillance over an important part of the public wealth.

Trial works are executed under the immediate inspection of the mining engineers, when the cost is provided for either by the Administration of Mines or by special funds voted for the purpose by departments or communes. Sometimes, also, the engineers, when authorized by the Administration, direct the works undertaken, at their own cost, by private persons.

The Administration of Mines is consulted upon projected researches, for which the permission of the government is necessary; and it watches over the execution of these projects. These permissions are only for a short period; and they are, moreover, few, because alone necessary when the proprietor of the surface opposes the working of his ground, a case which rarely occurs. When researches are to be made in communal ground, and the communes raise no objection, and when they are made in domanial forests, permission is granted either by the Minister of Commerce and Public Works, acting for the communes, or by the Minister of Finance, acting as administrator of state lands.

The police regulations for the mines require a periodical inspection of the underground workings, as well as of the machinery employed, a verification of the plans of the last year's working, and an examination of the plan and journal which should register the daily advance of the

works and contain those notes respecting the progress of the mine of which it may be useful to retain a record.

A minute of the visit is to be made, and instructions to be given in writing to the persons in charge of the mine, relatively to the measures to be adopted for the safety of the men and mine. An account has also to be rendered to the préfet of the condition of the works and of the manner in which the terms of the concession have been fulfilled.

Travels are undertaken by the mining engineers at the cost of the Administration of Mines, in order to enrich France by information respecting the discoveries made by, and facts observed in, other countries.

The engineers publish two volumes annually, under the title of 'Annales des Mines,' commenced in 1794 as the 'Journal des Mines,' but bearing since 1816 its present designation. Though the editing of this work is confided to a special commission, the whole corps takes a part in the work. The memoirs contained in it relate to mining, and to the sciences and arts bearing upon it.

The school of mines of Paris was founded by Louis XVI., in 1783, reorganised in 1794, and finally arranged in 1816. At the commencement, the course of study lasted three years, during which time the lectures were delivered only in the winter, whilst in summer the pupils accompanied the inspectors on their tours, or resided for a time amid the operations of mining. The qualifications necessary for entering as a pupil were,—completion of 16 years of age, a sufficient acquaintance with geometry, drawing, and German. The mining engineers, it was decided, should be selected only from these students.

From an elementary it was, in 1795, changed into a practical school, and the pupils, twenty in number, were chosen from those of the Ecole Polytechnique who had attained the greatest proficiency in mathematics.

In 1802, the establishment was removed to Pesey, in Savoy, where a lead mine was at that time worked by the state; and a second practical school was founded at Geislautern, in the old department of the Sarre.

After the events of 1814 and 1815 had deprived France of these two localities, the school of mines was re-established in Paris; and the number of "élèves ingénieurs" was reduced to nine, whilst the same number of extraordinary students (*élèves externes*) were admitted to a participation in the course, and were provided, on leaving the school, with certificates according to their proficiency, as proved by the result of annual examinations. The management, which was at first intrusted to one director, was now placed in the hands of the council, composed of the inspectors-general of the corps of mines, the professors, and the inspector of the educational department.

The course of study is under the direction of the engineers, and comprises mechanics, and the working of mines; assaying and laboratory

work in general; metallurgy, mineralogy, and geology. The pupils also receive instruction in drawing, surveying, and in the German and English languages.

The lectures occupy from the 15th of November to the 15th of April, and the duration of the course is two years, although the greater part of the students remain three years.

During the first year the intervals between the lectures are occupied with laboratory work, and surveying. The second and third year students employ the summer in travelling, with a view to visit mines and furnace works.

The lectures at the school of mines, without being public, are nevertheless attended by a large class of persons desirous of following up particular subjects. Besides the "élèves ingénieurs" and the "élèves externes," there are always twenty-five to thirty free or authorized students, and a number of young foreign engineers, Russians, Americans, and Spaniards, who come to profit by the instruction given in this establishment.

The collections intended to facilitate the course of study are very extensive: thus, the collection of minerals contains 6,400 specimens; of rocks, 600; mineralogical collection for the pupils, 2,000; statistical collection for France, 2,500; geology of France, 2,400; of geological formations, 4,000; general geology, 26,000; of fossils, 6,000; of metallurgical products, 6,000; of chemical products, 2,000; of models, 350; drawings of machines and furnaces, 500: in all, 102,850.

The following eminent men are appointed to conduct the course of education at the Ecole des Mines:—

Inspector of studies, Dufrénoy, chief engineer of 1st class.

PROFESSORS.

Dufrénoy, chief engineer of 1st class	Mineralogy.
Élie de Beaumont, chief engineer of 1st class . .	Geology.
Berthier, inspector-general, and director of laboratory Ebelmen, ordinary engineer of 2nd class, assistant .	Docimasy.
Combes, chief engineer of 2nd class	Art of Mining.
Le Play, chief engineer of 2nd class	Metallurgy.
Delaunay, ordinary engineer of 2nd class	Drawing, & application of descriptive Geometry.

The Miners' School at Saint Etienne, founded in 1816, enjoys the advantage of being situated in the midst of the coal district of the Loire, long celebrated for the richness of its mines, and now crowded with furnace works and manufactories, which have arisen within the last thirty years.

The institution was at first intended to educate mining captains, and master workmen; but as it was at an early period attended by the sons

of proprietors of mines and works, and by other young men who had already acquired a school education, it was found desirable, on the one hand, to establish a higher course of education than had at first been proposed, and on the other, to form an inferior class suitable to the condition of workmen: and this system was carried into effect by a royal ordonnance in 1831.

The instruction at the Miners' School is gratuitous; and free students who are either too advanced or too much occupied to take part in the whole course, are allowed to follow up certain subjects.

The preparation for admission required of the regular students consists in an acquaintance with elementary arithmetic, the metrical system, land-surveying, and the French language.

The course of study occupies two years; and comprises, in the first year, arithmetic, geometry, elements of algebra, trigonometry, plan-drawing, levelling, descriptive geometry and its application to masonry and carpentry; general chemistry, assaying, mineralogy, and book-keeping: in the second year, courses on mechanics and machines, the working of mines, metallurgy, and building.

The students of the working class, who desire admission, are expected to have passed through the ordinary course of the primary schools. During the first year they are instructed in weights and measures, the elements of geometry, plan-drawing and levelling, book-keeping and linear drawing: during the second year, in elementary physics, chemistry, and mechanics.

With a grant, which has never exceeded 21,000 francs (including 6,000 for rent), this school has succeeded in establishing large collections of every kind, a library, and chemical laboratory.

The regular students are frequently examined, and according to the result of a competition, at the close of the year, certificates of three classes are delivered to them on the completion of their studies.

The school is under the direction of the inspector-general of the mineralogical division, of which the department of the Loire forms a portion; and he is aided by the chief engineer of the mines of this department.

Three engineers of mines, who conduct the course of education, take part in the administrative council of the school. The officers in question were, in 1845, as follows:—

Roussel Galle, chief engineer of 1st class	Director.
Fénéon, chief engineer of second class .	Mineralogy and Geology.
Gruner, ordinary engineer of 1st class .	Chemistry and Metallurgy.
Reuss, élève ingénieur	Mechanical Introduction, Machinery, Working of Mines, and Building.
Janicot	Arithmetic and Accounts.
Duhaut	Geometry, Mapping, and Drawing.

Miners' School of Alais.

A third school was opened in 1845, at Alais, in the department du Gard, under the direction of an engineer of mines. It was intended to fill up a gap which was left by the other two schools, and still farther to extend the advantages of technical education, by instructing intelligent workmen who would afterwards occupy the situation of mining captains, or foremen of works.

Besides these institutions laboratories, specially destined for analysis, have been established in other places; the following being a list of the whole:—Paris; Saint Etienne (Loire); Clermont (Puy-de-Dôme); Grenoble (Isère); Alais (Gard); Marseille; Vicdessos (Ariége); and Vesoul (Haute Saône).

The Paris laboratory is, to a certain extent, the model on which the others have been founded.

W. W. S.

An Account of the Coal and Lignite raised, and of the Iron and Steel manufactured in France; as given in the 'Compte-Rendu des Travaux des Ingénieurs des Mines' for 1844.*

The number of mines of mineral fuel granted by the government in France, amounted in the commencement of 1844, to 399, of which 258 were worked in 1843. The total quantity of surface granted was 1,105,408 English statute acres. The raising of the produce and pumping of the water was effected by means of 118 machines moved by water, and 396 steam engines, estimated at 10,189 horse power. During the year 1843, the mines in work employed 29,528 men.

The produce of mineral fuel compared with that of 1842 exhibited an increase of 1,000,000† tons, and amounted as a whole to 3,670,000 tons, divided as follows:—

	Tons.
Anthracite	570,000
Hard coal, with small flame	160,000
Bituminous smithy coal	390,000
Bituminous flaming coal	1,940,000
Poor flaming coal	480,000
Lignite, &c.	130,000
	3,670,000

The consumpton of fossil fuel in the kingdom of France had increased during the previous 15 years even at a more rapid rate than the country could produce, in consequence of foreign mines having, during this period, taking a more prominent part in the supply of the manufactories, common fires, maritime arsenals, &c.

For the first time during ten years, there was diminution in 1843 in the quantity of coal imported from Great Britain,—a result probably due to the increase, in 1842, of the export dues from Great Britain. Since, however, these were again remitted in the beginning of 1845, it is likely that the import of British coal will again exhibit the progressive increase which had been remarked up to 1843. The following table gives the quantity of coal imported from Great Britain for each year:—

* By the 5th Article of the French law of the 23rd of April, 1833, it is enacted that an annual statement be published of the metallurgical, mineralogical, and geological works which the mining engineers (of France) should have executed, directed, or superintended; and that, at the opening of each session, such statement should be distributed to the members of the two Chambers.

† The unit of weight used by the French miners is one metrical quintal, or 100 kilogrammes; and, although the French tonne of 1000 kilogrammes is not quite equal to the English ton, we may for general purposes assume 10 metrical quintals to be equivalent to our ton.

Years.	Tons.	Years.	Tons.
1832	37,500	1838	300,000
1833	42,600	1839	320,000
1834	48,200	1840	380,000
1835	98,000	1841	424,000
1836	166,000	1842	490,000
1837	220,000	1843	450,000

The consumption of mineral fuel in France during the year 1842, amounted to 5,282,000 tons, which was derived from the following sources :—

	Tons.	Tons.	Tons.
Home Produce.			
Coal field of the Loire	1,290,000		
" Valenciennes	857,000		
" Alais	335,000		
" Creusot and Blanzy	225,000	3,682,000	
" Aubin	140,000		
67 other coal fields	835,000		5,343,000
Imported Coals.			
From Belgium	991,000		
" Great Britain*	455,000		
" the Rhenish Provinces	213,000	1,661,000	
" various countries	2,000		
Export of French Coal.			
To Belgium	31,200		
" Switzerland	10,300		
" Sardinia	6,810		
" Spain	5,400		
" Kingdom of Naples	870		61,000
" German States	1,400		
" Algeria	800		
" other French Colonies	2,420		
" various countries	1,800		
Difference, or home-consumption of France			5,282,000

The *iron manufacture* had rapidly developed itself, and the increase of produce was not less considerable in 1843, than during the preceding years.

From 1819 to 1843, the quantity of pig iron annually produced had increased from 120,000 tons to 420,000 tons, and that of bar or malleable iron from 74,000 to 300,000 tons. With regard to the importance of her smelting furnaces, France at present exceeds all the other powers of the continent of Europe, as will be seen by comparing the following numbers :—

	Pig Iron. Tons.	Forged Iron. Tons.
Produce of Russia (mean of 1835 to 1838)	180,000	102,000
" Sweden (mean of 1833 to 1839)	104,000	75,000
" " 1839	115,000	87,000
" Prussia, 1840	111,000	75,000

* There is here a difference from the statement before given.

The mining of the ores and the accessory labour expended in preparing them for smelting, and in their carriage to the works, had created in 1843 a total value of 15,490,410 francs, distributed as follows:—

	Francs.
Rent paid to Government, or the lords of the soil	1,573,345
Mining	5,651,798
Washing	1,683,984
Calcining	186,772
Carriage	6,394,511
	15,490,410

This produce corresponds very nearly with the consumption of the foundries, amounting to 1,200,000 tons, valued at 15,600,710 francs.

The mean price of a quintal (nearly two cwt.) delivered at the works, and prepared for smelting was in 1843, 1·297 francs, the different elements of expense being proportioned thus:—

	Francs.	Francs.
Rent	0·132	0·102
Mining	0·473	0·365
Washing	0·140	0·108
Calcining	0·016	0·012
Carriage	0·536	0·413
Total	1·297	1·000

If we subtract the rent from the other charges since it is unconnected with the actual mining operations, as also the carriage which is generally capable of very great improvement,—the price of the quintal of ore ready for smelting would be but ·629 francs. This sum is less than that obtained by the same calculation, for the greater part of the iron works of Europe, and particularly of Great Britain; and it affords an idea of the abundance of easily raised ore in France, whilst it proves that the progress of such works depends in a great degree on the perfection of the means of communication.

The pig iron produced in 1843, amounted to 416,170 tons, which may be subdivided as follows:—

	Tons.
Worked with charcoal	258,244
" wood (green, dried) alone, or mixed with charcoal	29,120
" charcoal and coke mixed	30,130
" coke alone, or mixed with coal	998,676
	416,170

Of the total quantity, 331,330 tons were intended for the refinery, and 84,840 tons for casting.

In the year 1782, the use of mineral fuel for iron smelting, was introduced into the department of the Saône-et-Loire, and in 1819 into the department of the Isère, on the Rhone; but notwithstanding the attempts

made about 1822 more generally to spread the application of coke, it was not until 1828 that it acquired any importance, and it is only since 1842, that it has commenced rising consistently with what might have been expected from the abundance of the ore, and the richness of the coal fields.

The following table exhibits the progressive increase, during 25 years, of the quantity of iron melted with coke and with charcoal.

Years.	With Coke. Tons.	With Charcoal. Tons.	Years.	With Coke. Tons.	With Charcoal. Tons.
1819	2,000	110,000	1833	39,200	196,500
1822	3,000	107,500	1834	47,000	221,500
1824	5,300	192,000	1835	48,100	246,000
1825	4,400	194,000	1836	46,100	262,000
1826	5,500	200,000	1837	62,500	268,500
1827	7,300	209,000	1838	69,200	278,000
1828	21,500	199,000	1839	66,200	283,500
1829	27,000	189,500	1840	77,000	270,500
1830	27,000	239,000	1841	85,000	291,500
1831	27,500	197,000	1842	102,000	297,000
1832	30,000	194,500			

About 1835 the increasing price of vegetable fuel, induced several iron masters to try the use of dried or torrefied wood instead of charcoal, with the view of turning to advantage a part of the combustible matter, which, in the usual mode of charcoal burning in the forests, is altogether lost. The result, however, was not so favourable as the first experiments had induced them to expect: in many places the economy obtained in the fuel was counterbalanced by the greater expense of carriage, whilst the action of the furnace became less regular, and in most cases it was necessary to mix a considerable portion of charcoal with the wood. Since 1839 this method has been falling more and more into disuse.

About 1833 the use of the hot blast was introduced into the French iron works, but its employment had not become so general as might have been expected in consequence of its known economy in fuel. The following table gives a general view of all the iron furnaces in blast, during the year 1842.

	Number of Furnaces.		
	Cold Blast.	Hot Blast.	Total.
Furnaces employing charcoal	332	52	384
" " wood, or mixed wood and charcoal	8	26	34
" " coal and coke	12	39	51
Total . .	352	117	469

During the last 25 years the annual quantity of iron has been greatly augmented by the increase both in the number of furnaces and in the quantity of their daily produce; the progressive increase in number may be seen as follows:—

Years.	Number of Furnaces in Blast.		
	With Charcoal or Wood.	With Coke alone, or mixed with Coal and Charcoal.	Total.
1819	348	2	350
1834	379	30	409
1835	410	28	438
1836	419	25	444
1837	433	34	467
1838	432	33	465
1839	445	33	478
1840	385	41	426
1841	426	42	468
1842	418	51	469

In 1819 the annual mean produce of a furnace was 315 tons, in 1842 it amounted to 827 tons. This considerable increase is due not only to the erection of a great number of furnaces for the use of coke, but to the improvements in the construction and management of those for charcoal, and above all in the greater power given to the blast engines. The furnaces for charcoal produce at present 699 tons per annum; those where a mixture of charcoal and coke is used produce 1034 tons, and those fired exclusively with mineral fuel, 2333 tons.

Under the circumstances in which most of the furnaces fired with vegetable fuel are placed, the mean annual produce is much checked by the insufficiency of water-power for the blast during the summer months. Among the improvements introduced into the management of this apparatus, the most important has been the mode of supplying this insufficiency by employing steam-engines whose boilers are heated by the combustible gases which otherwise were totally wasted in leaving the top of the furnace. Similar engines have been heated by the gases evolved from various other metallurgical fires, and the plan has met in France with such general approbation, that a considerable proportion of the motive power employed in the iron works, is obtained in this manner.

In 1842 the iron works employed 3000 machines, estimated at 25,002 horse power, which may be thus classed:—

	Machines.	Horse Power.
Steam-engines heated with coal	51	1,088
" " the gases rising from various metallurgical operations .	92	2,857
Hydraulic engines	2,857	21,057
	3,000	25,002

The manufacture of *malleable iron* has undergone a great change since the year 1818, when vegetable fuel alone was employed for this purpose. In 1843 the quantity produced was 303,743 tons, made up by the following variety of methods :—

	Tons.
Catalonian and Corsican method	10,675
Refinery of Comté	85,071
Walloon refinery	5,429
Nivernais	793
Modified method of Comté	10,961
Champagne	28,498
English	156,294
Treatment of scrap iron	6,022
	303,743

The first method, by which malleable iron is produced directly from the ore without any previous operation except calcining, has from the superior quality of its produce maintained its place during the last 25 years, notwithstanding the greatly increased price of wood, and the competition of coal iron ; in 1819 the quantity thus produced was 9045 tons, in 1843, 10,675 tons.

The other methods of preparing malleable iron with charcoal are fast yielding to those in which mineral fuel is employed. Between 1818 and 1820 the first steps towards this revolution were taken, in the departments of the Moselle, the Cher, and the Ile et Villaine, soon after which numerous works sprang up upon the coal fields of the Loire, Valenciennes, Alais, Aubin, Creuzot et Blanzy, &c.

The English system differs from those before employed on the continent, not only in the nature of the fuel and the form of the furnaces, but also in the mechanical means by which the iron is converted into bars. Many works, however, without the advantage of a large water power, have preserved their old hammers instead of substituting the rolling-mill, and this modification has been called the method of Champagne, from the district in which it has been most largely employed; but although it stood its ground for some years, it will probably yield by degrees to the more economical plan of the rolling-mills.

The application of mineral fuel to the working of iron has produced another result, which is observable also among some of the British works. Intermediate between the use of charcoal alone and that of coal or coke, there have arisen a number of mixed processes of combination, which have for their object the preservation of the good qualities of charcoal iron, and the attainment of the economy consequent on the use of coal and of the rolling mills. These varieties, comprised under the head of the modified method of Comté, are fast advancing in favour, at the expense of the old method of Comté, where charcoal and the

hammer were used. In 1837, there were but 3164 tons thus manufactured; in 1843, 10,961 tons. The English method has made a rapid advance in and about several of the coal fields; the quantity of iron produced by it was, in 1834, 36,058 tons; in 1843 it amounted to 156,294 tons. Yet the annual produce of malleable iron prepared with vegetable fuel has greatly increased during 25 years, from 1819 to 1842, as the following table will show:—

Years.	Malleable Iron, made with Charcoal.	Malleable Iron, made with Coke, wholly, or in part.	Total.
	Tons.	Tons.	Tons.
1819	72,028	9,843	81,871
1822	70,016	14,760	84,776
1824	97,995	41,427	139,422
1825	100,840	40,812	141,652
1826	103,257	39,940	143,197
1827	102,802	43,660	146,462
1828	101,145	47,820	148,965
1829	106,228	44,937	151,165
1830	99,988	46,105	146,093
1831	99,669	39,131	138,800
1832	97,590	43,603	141,193
1833	97,621	52,208	149,829
1834	100,454	73,876	174,330
1835	106,429	99,757	206,186
1836	109,146	98,065	207,211
1837	108,236	112,784	221,020
1838	107,340	114,269	221,609
1839	100,134	127,807	227,941
1840	101,652	131,929	233,581
1841	108,620	150,907	259,527
1842	108,039	172,228	280,267

The great obstacle to the advance of the French iron manufacture has been the price of fuel, though for the last twenty years the quantity of fuel required to produce a given quantity of iron has been continually decreasing. The proportionate expense, however, rose for some years, in consequence of the rapid extension of coal refineries not being accompanied by a corresponding increase of coke smelted iron; and it is only since 1839 that the price of charcoal has been falling, and with it the ratio of the expense of fuel to the value of iron has diminished.

The quantity of iron manufactured in France is not equal to the consumption of the forges and foundries, and in order to make up the necessary amount, iron is imported from Belgium, Great Britain, Germany, and Savoy: the pig iron required in 1843 to supply these works was,—

	Tons.
New pig iron, French . . .	416,170
New pig iron, foreign . . .	41,532
Old cast iron	47,716
	505,418

The manufacture of *forged steel* has remained for some time nearly stationary, like all the branches of metallurgical art dependent on the exclusive use of vegetable fuel. In 1843, but 3471 tons of rough steel were made, including 776 tons of a very ordinary quality, called *aciers de terre*, and employed in making agricultural implements. The manufacture of blistered steel, on the other hand, is in a very prosperous condition.

The produce of good pig irons for making forged steel, is peculiar to a very small number of mineral deposits, situated chiefly in Styria* and Corinthia, Westphalia, Thuringia, and the Alps of the Isère both in France and Savoy. Since, however, the expense of carriage is very great with a material like this, of which a large proportion is lost in the working, it is found advisable to import the produce of the German steel works in the form of rough steel, rather that in that of pig-iron.

The irons employed for the manufacture of cemented or blistered steel, are also only produced from ores of particular quality, which are not so rare as those above mentioned, but have been proved by long experience to be best produced in Sweden, Norway, and Russia. For nearly two centuries these irons have constantly been employed by the steel works in Yorkshire, and their treatment by cementation and casting produce the superior qualities of the English steel, which, with the German forge steel, is annually imported into France in considerable quantity, either in rough bars or manufactured articles.

The French manufacture of cemented steel, which remained stationary as long as they endeavoured to work up French iron, has increased rapidly, since, profiting by the experience of Great Britain, they have endeavoured to produce superior qualities by means of the Northern iron, and the progress of this manufacture would be much greater if the custom-house would favour the importation of the suitable kinds of iron, as it has already done with the pig iron used for making forge steel.

	Tons.		Tons.	
In 1826 France produced	1,476	of rough blistered steel,	155	cast steel.
„ 1843 „	5,719	„ „	1,595	„

Notwithstanding this remarkable advance in the French steel manufacture, the importation of foreign steel bears a higher relation to the home produce, if we estimate it by weight, and much more so, if by its pecuniary value, than any other branch of the iron trade. The relation of the quantity imported, to that of French manufacture, for pig iron, bar iron, and steel, were as follows in the year 1843:—

* The ores here alluded to are chiefly of the class called sparry iron, or the carbonate of the protoxide of iron, containing generally 50 per cent. of the protoxide of iron, and differing from the argillaceous carbonates used in Great Britain, in the absence of silica and alumina, and in the smaller per-centage of lime.

	Imported.	Produced in France.	Relation.
	Tons.	Tons.	Tons.
Pig	41,532	415,760	0·100
Bar iron . . .	7,286	303,510	0·024
Steel	1,303	9,190	0·142

The quantities of iron imported from Sweden, Norway, and Russia, have varied much during the last 13 years, but on the whole have much increased.

Years.	Sweden.	Norway.	Russia.	Total.
	Tons.	Tons,	Tons.	Tons.
1831	3,776	298	112	4,186
1843	5,481	65	578	6,124

There is reason to believe that within a short time the manufacture of iron in France will advance, even more rapidly than it has done of late years. Hitherto the smelting,—to which the after-processes are necessarily subordinate, has depended principally on the employment of vegetable fuel, and its produce has therefore been limited by the resources in wood, possessed by the district which furnished the ores.

Under such circumstances the development of the refining with coal in and around its chief coal fields, tended rather to raise the price of pig than to bring down that of bar iron ; and since, on the other hand, the increase in the produce of pig iron caused a corresponding demand for wood, the increase in the price of wood has at length been the cause of the numerous improvements introduced within the last twenty years.

The position of the French iron works is at present changing in a remarkable manner, since the smelting with mineral fuel has made a decided advance. The improvement of the internal navigation is daily increasing the number and the produce of the blast furnaces for coke ; thus the completion of the Berri Canal is giving rise to blast furnaces near the collieries of Commentry (Allier), to be supplied with the ironstone of the department of the Cher. The works which are in progress for the junction of the Saone with the Marne, by a canal carried through the midst of the works of Champagne, will give the strongest possible impulse to the French iron manufacture, since they will unite the coal field of the Loire with the ironstone deposits of the Haute Marne, the two richest tracts of the country in fuel and ore.

W. W. S.

A Notice of the Copper and Tin raised in Cornwall. By ROBERT HUNT, Keeper of Mining Records.

OF the early history of English copper-mining we have no authentic information. Tradition informs us that the Paris mountain in Anglesea was explored by the Romans; and one part still bears the name of "the Roman work."*

Cumberland appears to have been the only productive district for copper up to A. D. 1250, at which period a rich copper mine was worked near Keswick†; and still later, about 1670, the mines of Staffordshire‡ only are mentioned as producing any quantity of copper.

Edward III. granted by indenture, dated 11th of July, in the 32nd year of his reign, unto John Ballanter and Walter Bolbolter, "all his mines of gold, silver, and copper, in the Countie of Devon for two years;" but we have no account of any workings prosecuted by these adventurers.

In the reign of Henry VI. patents were granted to John Sollers, John Bottwright, and the Duke of York, for working "all mines of copper, tin, and lead," in Devon and Cornwall, "whereout any gold or silver shall be fined." It would, therefore, appear that although copper was known to exist in the rocks of Cornwall, it was only worked, if worked at all, with a view to separate the precious metals these ores were supposed to contain.

That the quantity of copper produced altogether in Britain, in the reign of Henry VIII. was very small, appears from the Acts of Parliament passed in the reigns of Henry VIII. and Edward VI., to prevent the exportation of brass and copper, "lest there should not be metal enough left in the kingdom fit for making of guns and other engines of war and for household utensils."§

* 'Pennant's Wales,' vol. iii. p. 59.

† The close rolls of Henry III. give some account of these Cumberland mines. A charter was granted to Keswick by Edward IV., A. D. 1470; and Camden states these copper works "were not only sufficient for all England, but great quantities of copper were exported every year."—*Gough's Camden's Britannia*, Edition, 1806, vol. iii. p. 432.

‡ See 'Natural History of Staffordshire,' by Robert Plot, L.L.D., Edit., 1686, chap. iv. sec. 28.

§ The metals prohibited were brass, copper, latten, bell metal, pan metal, gun metal, and shrof metal, 21 Henry VIII. c. 10, 33 Henry VIII. c. 7, 2 and 3 Edward VI. c. 37.—See 'Watson's Chemical Essays,' vol. iv. Ess. i. p. 75.

A patent for making brass was granted by Queen Elizabeth to William Humphry, and Christopher Shutz, in which they are permitted "to search, dig, and mine for the *calamine stone* in all parts of England." An incorporated society was afterwards formed for the same purpose, under the name of "The Society for Mineral and Battery Works." There is every reason to suppose the copper for this brass manufactory was imported; indeed, in 1665, amongst other reasons given by the brass manufacturers for asking for an increased imposition upon "Foreign Latten Weir," they state "that having an inexhaustible quantity of the calamine stone," "the continuing these works in England will occasion *plenty of rough copper to be brought in.*" *

The statements in Carew's Survey, written about 1586, and in Norden's, which is probably a little older, stating that copper found in Cornwall was sent to Wales to be smelted, are not to be brought as proof that any quantity of copper was then raised in Cornwall. It is probable that the copper lodes of Huel Trenwith and Huel Providence, near St. Ives, may have been known.†

It is certain, that up to the end of the seventeenth century the Cornish miners knew little of the value of copper ore. Borlase says:—"Some gentlemen from Bristol made it their business to inspect our mines more narrowly, and bought the copper raised for two pounds ten shillings per ton, and scarce ever more than for four pounds per ton. It must be observed that the yellow ore which now sells for a price between ten and twenty pounds per ton, was at this time called *Poder* (that is, dust), and thrown away as mundic."‡

Shortly after 1700 Mr. John Costar introduced an hydraulic engine into Cornwall, and succeeded in successfully draining some of the mines, and "he taught the people of Cornwall also a better way of assaying and dressing the ore."

* Fodinæ Regales, p. 72.

† 'Geological Report on Devon and Cornwall,' Sir Henry De la Beche, p. 532. Mr. Carne, on 'Copper Mining in Cornwall,' 'Transactions of the Royal Geological Society of Cornwall,' vol. iii. p. 41.

‡ 'Borlase's Natural History of Cornwall,' 1758, p. 205. In a note it is stated that the copper ores of N'uun-vian, in Piranuthno, and at Mr. Ustick's works in St. Just, were sold at the price named in the text; and that "Mr. Beauchamp, of Gwennap, at this time (1718), covenanted to sell all the copper which should rise out of a mine well stocked, for twenty years, at five pounds per ton, and the ore at Relistian, in Gwinear, was covenanted for at two pounds ten shillings per ton. Sir Henry De la Beche imagines this term rather to apply to the black copper ore, and in a note on this subject says:—"As *poder* means dust, which would agree with the appearance of this friable ore, it may be questionable how far Borlase may have been correct in stating that the yellow copper was thus named. As *poder* has this meaning, may not the name be merely a provincial manner of pronouncing the English word *powder*."—*Geological Report of Devon, Cornwall, &c.*, p. 591.

From this time the quantity of copper produced in Cornwall has gradually increased. The following table, arranged from two given in Pryce's 'Mineralogia Cornubiensis,' will exhibit the earliest conditions of the Cornish copper market on which any reliance can be placed.

Date.	Tons.	Average price per Ton.	Date.	Tons.	Average price per Ton.
1726	5,000	£. s. d. 7 15 10	1736	8,000	£. s. d. 7 8 6
1727	6,700		1737	9,000	
1728	6,800		1738	10,000	
1729	6,870		1739	11,000	
1730	6,900		1740	5,000	
1731	7,000		1741	5,500	
1732	7,290		1742	6,050	
1733	7,000		1743	7,040	
1734	6,000				
1735	5,240				

From this period to the end of 1844 an attempt has been made to show the progress of copper-mining in a diagram, plate 9.

It has not been thought advisable to crowd the diagram unnecessarily, therefore the prices given per ton for copper ore at different periods has been omitted. The following table will, however, present a tolerably complete view of the principle variations in the average price of the Cornish copper ore:—

Years.	£. s. d.	Years.	£. s. d.
1700	2 10 0*	1805	10 1 10‡
1730	7 15 10	1814	8 15 4
1750	7 6 6†	1822	6 7 0
1779	5 16 0	1832	6 1 6
1797	7 17 8	1842	6 4 4

The low price per ton of Cornish copper in 1779, appears to have arisen from the immense quantities of copper thrown into the market from the Anglesea mines. These were discovered in 1768. In 1784 they produced 3000 tons of copper annually, and about the same period a great copper mine at Ecton Hill, in Staffordshire was also discovered, its most productive period being about 1780. § By throwing into the market at once, as much ore as could be raised from these mines, the price of copper was much reduced, and considerable injury inflicted upon the copper mines in general. ‖

* 'Borlase's Natural History of Cornwall.'

† In 1758 Borlase says, "Yellow ore now sells for a price between ten and twenty pounds *per* ton."

‡ It will be seen on reference to the chart that in this year the standard was unusually high. The cause of this high price appears to have been simply that the demand greatly exceeded the supply.

§ Mr. Carne, on Copper Mining in Cornwall, 'Transactions of the Royal Geological Society of Cornwall,' vol. iii.—Plot's 'History of Staffordshire.' Edition, 1686, p. 165.

‖ Much additional information respecting the mines of Cornwall will be found in the 'Geological Report of Cornwall, Devon, and West Somerset,' by Sir Henry De la Beche.

The terms "copper ore standard" being used in the diagram, it is necessary to explain that the "standard" means the price paid the miner for the copper in the ore, from which are deducted the expenses of bringing it to a state of purity. The sum deducted for these expenses since 1805, has been 55*s.* for every ton of ore.*

The quantity of copper ore raised in the county, between 1789 and 1794, it is now impossible to ascertain. This arises, it would appear, from the agitation spread through the mines of Cornwall at this period, from the disputes between Bolton and Watt, and Bull and Hornblower, respecting the infringement by the latter parties of Bolton and Watt's patent for their improved engine for pumping the waters from the mines, the consequence of which was a desire on all sides to keep secret as much of their proceedings as possible.†

In addition to the copper ores of Cornwall, the quantity of tin ore, and its produce in tons and blocks is also represented on the diagram up to the end of 1838, beyond which time, from the coinages being abandoned, it was impracticable to continue the account with anything like accuracy.

The following tables will exhibit a curious relation between the duration of several Cornish copper mines and their average produce of copper.

During 30 years, from 1815 to 1845, the number of mines in Cornwall which have sold at the public ticketings parcels of upwards of five tons of copper ores, are 220. The duration of these mines appears to have been as follows:—

20 Years and upwards.	10 Years and upwards, but under 20 Years.	5 Years and upwards, but under 10 Years	Less than 5 Years.
35	40	31	114

Average per centage produce of the 220 mines for the entire period above named 7¾
Highest average produce of copper from the ores of one mine 26¼
Lowest average produce of one mine 2¾

The average produce of the above number of mines, taken according to the duration of their works, is shown in the following

* 'Transactions of the Royal Geological Society of Cornwall,' vol. ii.

† For a detailed account of this disputed patent, see 'Tredgold on the Steam Engine, Appendix G.,' 'A Treatise on the Cornish Pumping Engine,' by William Pole, F.R.A.S., &c. See also, Taylor's 'Records of Mining,' and Lean's 'Historical Statement of the Improvements made in the Duty performed by the Steam Engines in Cornwall.'

Table of the Average per Centage produce of the 220 Mines with reference to the Length of time during which they continued at work.

	35 Mines at work upwards of 20 Years.	40 Mines at work upwards of 10 Years, but under 20.	31 Mines at work, upwards of 5 Years, but under 10.	114 Mines at work less than 5 Years.
Average per centage produce of fine copper	$7\frac{3}{8}$	$7\frac{5}{8}$	$7\frac{7}{8}$	$8\frac{1}{8}$
Highest average per centage produce of a single mine	$13\frac{5}{8}$	14	$14\frac{1}{8}$	$26\frac{1}{8}$
Lowest average per centage produce of a single mine	$4\frac{5}{8}$	$4\frac{7}{8}$	$5\frac{1}{8}$	$2\frac{7}{8}$
Number of mines producing above 25 per cent. of copper	..	..	..	2
Number of mines producing above 15 per cent.	..	..	..	4
Number of mines producing above 10 per cent.	2	4	2	13
Number of mines producing above 5 per cent	32	34	29	70
Number of mines producing less than 5 per cent.	1	2	..	8

The names of the mines, and the average per-centage produce of each, is given in the following lists:—

Mines which have been worked more than 20 Years.

1. Tresavean	$7\frac{5}{8}$	20. Consolidated Mines. . .	$8\frac{1}{8}$
2. United Mines.	$8\frac{1}{8}$	21. Pembroke	$8\frac{3}{8}$
3. Dolcoath	$7\frac{3}{8}$	22. North Downs. . . .	$7\frac{7}{8}$
4. North Roskear	$7\frac{1}{8}$	23. Creeg-braws	$7\frac{1}{8}$
5. South Roskear	8	24. Huel Jewel	$8\frac{3}{8}$
6. South Huel Buller and Beauchamp*	$6\frac{7}{8}$	25. Tingtang	$8\frac{3}{8}$
7. Fowey Consols	$7\frac{5}{8}$	26. Great St. George . . .	$6\frac{5}{8}$
8. Botallack	$12\frac{7}{8}$	27. St. Towan	$6\frac{1}{8}$
9. Levant	$13\frac{5}{8}$	28. Huel Harmony . . .	$9\frac{7}{8}$
10. Huel Alfred	6	29. Penstruthal	6
11. Crinnis	$6\frac{5}{8}$	30. Huel Maid and Carharach.	$7\frac{3}{8}$
12. East Crinnis	$8\frac{7}{8}$	31. Binner Downs . . .	$7\frac{1}{8}$
13. Huel Unity and Poldice . .	$8\frac{5}{8}$	32. Huel Busy	$4\frac{5}{8}$
14. Treskerby and Huel Chance .	$9\frac{1}{8}$	33. Huel Trenwith . . .	$9\frac{7}{8}$
15. Huel Damsel	$8\frac{3}{8}$	34. Huel Mary	8
16. Huel Basset	$9\frac{1}{8}$	35. United Hills	$7\frac{1}{8}$
17. Huel Gorland.	$8\frac{1}{8}$		
18. Cook's Kitchen	$6\frac{3}{8}$		$7\frac{3}{8}$
19. Camborn Vean	$8\frac{1}{8}$		

Average produce per cent. of 35 Mines . . .	$7\frac{3}{8}$
Highest Produce	$13\frac{5}{8}$
Lowest Produce	$4\frac{5}{8}$
Above 25 per cent.	0
Above 15	0
Above 10	2
Above 5	32
Under 5	1

* *Huel* is an old Cornish term, signifying, according to Pryce, "a work, a mine; as, *huel* stone, a tin mine; *huel kalish*, a hard work." This term, used by Borlase and all the older writers on the subject, has been by degrees corrupted into *wheal*.

Mines which have been worked more than 10 Years.

1. Great Work	10⅜	22. Huel Hope	8⅝
2. Huel Cock	10 1/16	23. Cardew	6⅛
3. Huel Abraham	6⅛	24. Huel Towan	6⅛
4. Huel Fortune	7⅛	25. Huel Unity Wood	8
5. Chacewater	6⅜	26. Huel Vyvyan	6⅛
6. Godolphin	7⅜	27. Huel Leisure	6⅝
7. Trenoweth	4⅞	28. Huel Darlington	7⅜
8. Huel Clowance	8⅜	29. Carn Brea	8⅜
9. Cuddra	7⅞	30. East Pool	9⅝
10. Tregajoran	12⅛	31. Hallenbeagle	6⅝
11. Huel Squire	8⅜	32. Huel Providence	8⅝
12. Huel Sparrow	6⅞	33. Providence Mines	8⅝
13. Huel Music	14	34. Huel Harriet	5
14. Marazion Mines	7⅝	35. Huel Virgin	7⅛
15. Huel Strawberry	6⅝	36. Relistian	8⅝
16. Huel Speedwell	7⅛	37. South Huel Basset	8⅜
17. Carzise	8⅝	38. Huel Neptune	9⅜
18. Huel Charlotte	8⅞	39. Tin Croft	6 1/16
19. Lanescott	8⅝	40. Huel Crofty	7⅜
20. Huel Vor	7⅝		
21. Huel Trannack	6⅛		7⅝

Average produce per cent of 40 Mines	7⅝
Highest Produce	14
Lowest Produce	4⅞
Above 25 per cent.	0
Above 15	0
Above 10	4
Above 5	34
Five, and less	2

Mines which have been worked more than 5 Years.

1. Trethellan	5⅝	18. Huel Elizabeth	6⅞
2. Huel Buller	8⅝	19. Retallack	8⅞
3. Huel Friendship	6⅜	20. Huel Wellington	7⅜
4. Huel Fanny	8⅞	21. Trewavas	8⅜
5. Weeth	14⅛	22. Huel Julia	8⅜
6. Huel Sparrow	8⅛	23. Copper Bottom	8⅛
7. Lambo	8⅞	24. Huel Kitty	9⅛
8. Unanimity	7⅛	25. Huel Treasury	6⅛
9. Huel Treasure	7⅜	26. Huel Vyvyan	5⅛
10. Huel Perran	7 1/16	27. St. Ives Consols	9⅝
11. Penberthy Crofts	7⅛	28. South Carradon	9
12. North Seal Hole	7⅛	29. Huel Carradon	9⅛
13. Huel Tehidy	8⅜	30. Huel Curtis	6⅛
14. Huel Pink	10	31. Par. Consols	8⅝
15. Huel Bolton	6⅝		
16. Huel Rodney	6⅜		7⅞
17. Huel Caroline	6⅜		

Average Produce per cent. of 31 Mines	7⅞
Highest Produce (Weeth)	14⅛
Lowest Produce (Huel Vyvyan)	5⅛
Above 25 per cent.	0
Above 15	0
Above 10, and 10	2
Above 5	29
Under 5	0

Mines which have been worked less than 5 Years.

1.	Polgooth	$8\frac{3}{8}$
2.	Boscean.	
3.	Huel Clifford.	
4.	Treleigh Consuls.	
5.	Tretoil.	
6.	Trevaskus.	
7.	Huel Trevole.	$8\frac{1}{16}$
8.	Boscaswell.	
9.	St. Carradon.	
10.	Tincroft.	
11.	Reith Consuls.	
12.	Huel Andrew.	
13.	Chiverton.	
14.	Bosorn.	
15.	Bal-u-hale.	
16.	Huel Cole	$7\frac{5}{8}$
17.	Huel Maitland.	
18.	Huel Owls.	
19.	Parkenoweth.	
20.	Spearn	11
21.	Spearn Moor	26
22.	Redruth Consuls	$6\frac{7}{8}$
23.	St. Huel Rose.	
24.	W. Huel Cock	$6\frac{5}{8}$
25.	Poldice	7
26.	Huel Drewellas	$9\frac{5}{8}$
27.	Huel Tamer	$6\frac{5}{8}$
28.	Huel Spinster	$8\frac{3}{8}$
29.	Perran Vale	$6\frac{7}{8}$
30.	Carn Perran	$7\frac{3}{8}$
31.	Penwinnick	$7\frac{3}{8}$
32.	St. George	$9\frac{5}{8}$
33.	Druid	$18\frac{1}{8}$
34.	Huel Sperris	$5\frac{5}{8}$
35.	Pobreen	$19\frac{7}{8}$
36.	Huel Ann	$6\frac{1}{8}$
37.	Huel Regent	$8\frac{7}{8}$
38.	Herland	$12\frac{5}{8}$
39.	Huel Jubilee	$7\frac{3}{8}$
40.	Huel Commerce	10
41.	Huel Mary	$5\frac{5}{8}$
42.	Legossick	$7\frac{5}{8}$
43.	Condorrow	9
44.	Huel Falmouth	$6\frac{3}{8}$
45.	Huel Great Falmouth	$7\frac{5}{8}$
46.	Polgine	8
47.	Huel Bank	$9\frac{5}{8}$
48.	Huel Rock	$6\frac{1}{8}$
49.	Huel Seaton	$8\frac{7}{8}$
50.	Huel Asborne	$8\frac{5}{8}$
51.	Sydney Cove	$8\frac{1}{16}$
52.	Tregothnan	$5\frac{5}{8}$
53.	Huel Chippendale	$7\frac{3}{8}$
54.	Huel Messer	$8\frac{3}{8}$
55.	Bolenna	$3\frac{5}{8}$
56.	Phœnix Mine	$12\frac{7}{8}$
57.	Huel Penrose.	$7\frac{5}{8}$
58.	Grambla and St. Aubyn	$8\frac{5}{8}$
59.	Huel St. Francis	$6\frac{5}{8}$
60.	Huel Marden	$6\frac{5}{8}$
61.	West Fowey Consols	$8\frac{3}{8}$
62.	Lancoit Consols	$7\frac{5}{8}$
63.	Mark Valley.	$4\frac{7}{8}$
64.	Burncoose	$11\frac{5}{8}$
65.	Charlestown	$6\frac{3}{8}$
66.	Charlestown United	$16\frac{3}{8}$
67.	Trelissick	$5\frac{1}{8}$
68.	Huel Mulvra	$15\frac{5}{8}$
69.	Huel Tolgus	$7\frac{1}{8}$
70.	Huel Liscott	$7\frac{1}{8}$
71.	Huel Penwith	$13\frac{5}{8}$
72.	Pendarves	$4\frac{1}{8}$
73.	Great Hewas	$6\frac{5}{8}$
74.	Copperhouse	$6\frac{3}{8}$
75.	Boiling Well	$11\frac{5}{8}$
76.	Penandrea	$7\frac{3}{8}$
77.	Huel Charles	$6\frac{3}{8}$
78.	Huel Prudence	12
79.	Huel Edward.	$14\frac{1}{8}$
80.	Long Clothes.	$5\frac{1}{8}$
81.	Huel Primrose	$6\frac{1}{8}$
82.	Bennar Wood	$7\frac{1}{16}$
83.	Buckfastleigh	6
84.	Huel Lamb	$4\frac{5}{8}$
85.	Huel Susan	5
86.	George the Fourth	$6\frac{3}{8}$
87.	Treven.	$11\frac{3}{8}$
88.	Roseplethan	$3\frac{1}{8}$
89.	Friendly Mines	$9\frac{1}{8}$
90.	Cliff Downs	$5\frac{3}{8}$
91.	Lanin	$7\frac{7}{8}$
92.	Huel Maudlin.	$9\frac{1}{16}$
93.	Barton	$26\frac{1}{8}$
94.	Cabilla	$9\frac{5}{8}$
95.	Huel Cecilia	$2\frac{7}{8}$
96.	Huel Gerry	$4\frac{1}{8}$
97.	Huel Raven	$7\frac{7}{8}$
98.	Prince Royal	$8\frac{3}{8}$
99.	Huel Sisters	12
100.	Huel Valley	$6\frac{3}{8}$
101.	Huel Prosper	$8\frac{2}{7}$
102.	Huel Speed	$7\frac{1}{8}$
103.	Huel Kayle	$13\frac{3}{8}$
104.	Huel Uny	$7\frac{3}{8}$
105.	Huel Bolton	$6\frac{1}{8}$
106.	Huel Nicholls	$8\frac{1}{8}$
107.	Huel Trevabyn	$5\frac{1}{8}$
108.	Huel Ellen	$7\frac{3}{8}$

109. Huel Liberty	$4\frac{5}{8}$	113. Huel Burrow	$3\frac{5}{8}$
110. Huel Clifton	5	114. Huel Plenty	$7\frac{1}{8}$
111. Huel Duffield	$10\frac{1}{8}$		
112. Huel Leeds	$7\frac{1}{8}$		97) $826\frac{11}{16}$
			$8\frac{1}{8}$

Average Produce of 97 Mines	$8\frac{5}{8}$
Highest Produce (Barton)	$26\frac{1}{8}$
Lowest Produce (Huel Cecilia)	$2\frac{7}{8}$
Above 25 per cent.	2
Above 15 per cent., and under 20	4
Above 10 per cent., and under 15	13
Above 5 per cent., and under 10	70
Under 5 per cent.	8

Intimately connected with the progress of mining in Cornwall is the introduction and gradual improvement of the steam-engine. Before its introduction, the lift or force-pump was employed in the shallow mines, whilst from those which were deeper, the water was drawn out in buckets or barrels, raised to the surface by means of a wheel worked by horses. In many of the mines the chain-pump, fixed on stages at different depths, was used, and where water power could be obtained, it was eagerly applied by means of large wheels to give motion to pumps fixed in the shafts of the mines. Up to about the year 1700 few of the wheels employed were more than twelve feet in diameter, and there were not any whose diameter exceeded fifteen feet. Mr. John Costar, of Bristol, appears to have been the first person who introduced larger wheels than those; and to many of the Cornish mines he applied water-wheels of thirty to forty feet diameter, with great success.

About this time, attempts were made to introduce into the Cornish mines machines for raising water by the agency of steam, but without success. Savery tried hard to induce the Cornish miners to adopt his invention "of raising water by the impellent force of fire," but many objections were raised against the practical application of his engine, and it does not appear to have been ever introduced into Cornwall.

Dr. Pryce, in his 'Mineralogia Cornubiensis,' says, "Captain Savery was the first who erected an engine in the form we have since had them, and which has been lately improved by Mr. Blakey, though not to a degree of power sufficient to unwater a deep mine."

The first steam-engine erected in Cornwall appears to have been set to work in 1712 or 1713, at Huel Vor, a tin mine in Breage. Whether this was Savery's or Newcomen's is doubtful,* but it was in all probability Newcomen's, whose engine was brought into use in 1712, and from that period became generally employed, and has been since known under the name of the *Old Atmospheric Engine*. The second engine was erected at Huel Fortune, in Ludgvan, in 1720.

* Carne, 'Geological Transactions.' Newcomen's first engine was erected at the collieries in Warwickshire, 1711.

The progress of the steam-engine in Cornwall was, however, exceedingly slow, for, except the two above mentioned, we do not hear of any having been erected for several years; indeed, Price, in his 'Mineralogia Cornubiensis,' states, that thirty-six years before he wrote (1778), the county had but one fire-engine.

The immense advantage derived from the improvements introduced by Bolton and Watt led to the introduction of steam-engines, by degrees, into most of the Cornish mines; and since the adoption of the system of reporting the duties of these engines, a considerable advantage has been gained. The following table will show the gradual manner in which this improvement has taken place:—

A Table showing the duty performed by Steam Engines in Cornwall; also the average and highest duty performed by the best Engines in each monthly report. *

Years.	Highest duty performed.	Name of Mine whose Engine gives highest duty.	Average monthly duty of the best Engines.	Average monthly duty of all the Engines reported.	Number of Engines reported.	Coals consumed.	
						Average No. of Bushels of 94 lbs. per Month.	Bushels by each Engine per Month.
1813	29·76	Stray Park . .	26·65	19·45	24	..	..
1814	35·	„	32·	20·53	29	..	..
1815	34· 1	„	30·52	20·52	35	..	..
1816	40·74	Dolcoath . .	32· 4	22·90	32	..	..
1817	44· 2	„	41· 6	26·50	31	..	..
1818	42· 6	„	39· 3	25·43	32	..	..
1819	48· 5	„	40·	26·25	37	..	..
1820	48· 6	„	41· 3	28·73	37	..	..
1821	46· 6	„	42· 8	28·22	39	..	..
1822	44·16	Consolidated Mines	42· 5	28·88	45	..	..
1823	45·98	„	42·12	28·15	45	..	..
1824	46·76	Polgooth . .	43· 5	28·32	45	..	..
1825	53·95	„	45· 4	32·	50	..	..
1826	49·97	Huel Vor . .	45· 2	30·48	48	..	..
1827	67·09	Consolidated Mines	59·67	32· 1	47	..	..
1828	87·04	Huel Towan .	76·67	37· 3	54	..	..
1829	81·99	„	76·23	41·22	52	..	..
1830	77·99	„	75·88	43·35	55	..	..
1831	80·08	„	74·91	44· 7	54	81,867	1,488
1832	91·35	Huel Vor . .	79·29	44· 4	60	83,480	1,346
1833	88 50	„	83·30	46·	58	88,321	1,503
1834	97·85	Fowey Consols	86·25	46·86	57	78,057	1,363
1835	95·76	„	91·67	46·45	66	81,979	1,225
1836	97·59	„	89·59	45·61	71	101,246	1,405
1837	91·98	„	87·68	47·46	70	106,275	1,509
1838	91·59	„	84·88	47·84	70	112,631	1,566
1839	85·17	Godolphin . .	82·29	48·88	74	129,801	1,740
1840	85·28	Fowey Consols	81·80	49·73	58	203,699	1,746
1841	101·71	United Mines .	95·23	50·99	51	89,806	1,733
1842	107·49	„	99·26	51·62	45	84,862	1,848
1843	105·71	„	99·35	55·23	40	72,913	1,811
1844	98·72	„	94·89	54·73	35	62,292	1,763
1845	96· 0	„	91· 2	55·64	36	62,148	1,715

* The first portion of this Table to the end of the year 1828 has been already published by John Taylor, F. R. S., &c., in the 'Records of Mining.'

A detailed account of the progress of the steam-engine, towards its present state of perfection, will be found in Taylor's 'Records of Mining,' and in 'A Treatise on the Cornish Pumping Engine,' by William Pole, F.R.A.S., &c.

Additional Note.

In 'A New Description of England and Wales,' by Herman Moll, geographer—edition, 1724—the following passage occurs:—"About five-and-thirty years ago, Sir *Gilbert Clerk*, who was chymically inclined, coming into this county, and finding this mundick, or copper oar, to be of value, he began to smelt it; however, being not able to bring it to due perfection, some that were his agents erected smelting-houses in Bristol and Redbrooke, and, improving yearly in their work, we have now as good copper in England as in Sweden, and our country affording plenty of *Lapis Calaminaris*, we make as good brass as in any part of the world; and 'tis computed that no less than a hundred thousand hands are one way or other employed in working and manufacturing this oar." (p. 18.)

INDEX

TO THE FIRST VOLUME.

Abra, pleistocene species of, 409
Academy for Miners in Saxony, 486
Accumulations, kind of, at the mouths of rivers in tideless seas, 8
Accumulations, volcanic and ordinary in deep seas, 3
Actinic force, magnetism probably due to, 458
Administration of Mines in France, 496
Adolphe Brongniart, his opinion respecting the origin of coal, 152
Agassiz, Professor, on the glacial epoch, 400
Aikin, Dr., his notice of peculiar bed beneath coal, 147
Airy, Professor, on terrestrial magnetism, 458
Algæ, their distribution, 353; pelagic, species of, 349; their range in depth, 374; coast-line species of, 373
Altenberg and Zinnwald, 489
America, North, Mollusca of, 367, 378, 380; zoology of, 382, 396
Ampère, M., theory of, 434
Analysis of cornstone and red marls associated with it, from the old red sandstone of Milford Haven, 63
Analysis of Wenlock limestone of May Hill, 39; of red and gray marls of old red sandstone, 54
Ancient coast, its extent, 320
Ancient land around which the coal measures accumulated, 314
Ancient lines of coast and coast cliffs, 331
'Annales des Mines,' publication of, 497
Annellida, pleistocene species of, 431
Anomia, pleistocene species of, 420
Anthracite of South Wales, 217; passage of, into bituminous coal, 217; remarks upon the passage, 219; artificial, 220
Anthracitic mines, explosive gas of, 477
Antimony, diamagnetic character, 445
Aporrhais, pleistocene species of, 423
Arbor Dianæ, arrangement under magnetic influence, 439
Artemis, pleistocene species of, 414
Articulata, British marine, 355; fossil, 430
Asaphus Buchii, abundance of, in parts of South Wales, 31
Ashes, volcanic, distribution of, 2
Astarte, pleistocene species of, 412
Asturias, relation of its flora to that of Ireland, 347
Atlantic breakers, their ancient effects on Wales and its neighbourhood, 333
Atmosphere, supposed greater abundance of carbonic acid in, during early geological times, 36
Atmospheric influences and the power of running water, their effects on the surface, 332
Aust Cliff, Severn, section of new red marls and lias of, 253
Austen, his labours respecting South Devonian rocks, 87; his list of organic remains found in Newton Quarry, 88; discovered organic remains in volcanic ash of South Devonian rocks, 90; remarks on the coral reef character of South Devon limestones, 93; on habits of the marine animals of the time, *ib.*
Austrian Miner, condition of, 491

Balanus, pleistocene species of, 430
Bampton, passage of Pilton Group into carbonaceous rocks near, 136
Barry Island, Glamorganshire, dolomitic conglomerate and new red sandstone of, 245
Bars, mode of formation of, 15
Bath-brick laminated by electricity, 453
Beach character of certain conglomerates of Silurian date near Builth, 36
Becquerel, M., on the chemical power of voltaic current, 455
Bensham Seam, Hebburn Pit, analysis of gas from, 472
Bensham Seam, Jarrow, analysis of gas from, 471
Binney, Mr., on a bank thrown up by the sea, 478
Bischoff, researches of, 460
Bismuth, chloride of, diamagnetic character of, 445
Bismuth, nitrate of, diamagnetic character of, 445
Black limestones and associated beds of Muddlebridge, North Devon, 135; difficulty of drawing a boundary line between these beds and the Pilton Group, *ib.*;

continuation of the same series of deposits eastwards in North Devon, 136
Bolton and Watt's engines, 513, 517
Braunsdorf, mines at, 489
Breakers, action of, in great lakes and tideless seas, 11; action of, on tidal coasts, *ib.*
Breakers, movement of beach by, 12
Breakers, piling action of, in shallow water, 15
Brent Tor, ancient volcanic rocks of, 137
Bridlington, tertiary beds of, 392
Bristol, section of coal measures of, 207
Bristol, smelting at, 511
British Isles, peculiarities of their vegetation, 338; of their zoology, 342, 354
Broad Haven, Pembrokeshire, contortion of coal measures near, 227
Buccinum, pleistocene species of, 426
Buckland, Dr., and Conybeare, Rev. W. D., on the conglomerates of the lias near Shepton Mallet, 277; on the overlap by inferior oolite in the Mendip Hills, 287
Buckland, Dr., and Mr. Conybeare, notice of carbonate of magnesia in the carboniferous limestones of the Bristol district, 127; arch of carboniferous limestone in Glamorganshire, pointed out by, 130; millstone grit of the south-west coal fields, mentioned by, 144; connexion of the south-western coal fields, pointed out by, 157; divisions in coal measures of Bristol, established by, 206; contortions of older rocks in South Wales and South-Western England, noticed by, 223
Buckland, Dr., and Mr. Conybeare, observations respecting dolomitic conglomerate and new red sandstone, 240
Buckland, Dr., remarks on the origin of coal, 152; observations on upright stems of plants in coal measures, 184
Buddle, his notice of furrows in coal beds in Dean Forest, 156
Builth, Silurian rocks of, 22
Bull and Hornblower's engines, 513
Bulla, pleistocene species of, 430
Bunsen, Professor, analysis of gases by, 461

Caermarthen, Silurian rocks of, 25
Calcareous deposits, mode of formation of, 17
Calcareous rock, remarkable decomposition of, near Llangammarch, 40
Calorific radiations, magnetism perhaps due to, 458
Cancellaria, pleistocene species of, 428
Capulus, pleistocene species of, 422
Caradoc sandstone, limits of, towards South Wales, 37
Carbonaceous limestone of Devon, northern range of, 135; southern range of, 138
Carbonate of lime, large collective amount of, in the harder parts of many animals, 17
Carbonic acid, determination of, in coal gas, 464
Carbonic oxide, determination of, 467
Carboniferous limestone, section of, Caldy Island, Pembrokeshire, 111; thickness of encrinal accumulations in, 112; decrease of thickness, in its northern range in South Wales, *ib.*; section of, with lower part of the coal measures, and upper part of the old red sandstone, near Bristol, 113; oolitic limestone in, 125; general character of, Mendip Hills, Somerset, 127; section of, Lower Purlieu, Forest of Dean, *ib.*; hematite iron, accumulation in the carboniferous limestone of Dean Forest, 130; range of, from Pont y pool to Llantrissant, and arch of, in Glamorganshire, 130; general view of the thickness, and probable northern boundary of, from the Mendip Hills to Pembrokeshire, 131
Carboniferous limestone, section of beds immediately above Bishopstow, Gower, Glamorganshire, 133; continuation of, the same upper beds at Tenby, 134
Carboniferous limestone, section of lower part of West Angle Bay, Pembrokeshire, 106; section of junction of, with old red sandstone, Skrinkle Haven, Pembrokeshire, 108; general view of, in South Wales and South Western England, 142; plants, fossil, in the old red sandstone, 55, 58, 76, 107
Cardita, pleistocene species of, 414
Cardium, pleistocene species of, 416
Cassius, purple of, diamagnetic character of, 443
Caves at Gogofau, tradition of, 483
Cellepora, pleistocene species of, 432
Cemoria, pleistocene species of, 421
Cerithium, pleistocene species of, 423
Channel Isles, flora of the, 338
Chemical affinity, influence of magnetism on, 448
Clay, lamination of, 451
Clays, sands, and gravels, alternations of, containing different kinds of organic remains, 9
Clifton Downs, section of dolomitic conglomerate of, 247
Coal, composition of, 219
Coal, gases evolved during the formation of, 460
Coal and lignite raised, and of the iron and steel manufactured in France, 501
Coal measures, lower beds of, South Wales, and South Western England, 143
Coal measures, section of, from Wiseman's Bridge to the northward, Pembrokeshire, 161; section of the lower, Merthyr Tydfil, 169; section of the lower, Pont y pool, Monmouthshire, 174; section of the lower, Cefn Crebwr, Glamorganshire, 176; lower, remarks respecting, 178; section of, at Maesteg, Glamorganshire, 189; section of, near Swansea, 197; higher, section of, near Pont y pool, 201; thickness of, in South Wales, 202; section

of, in Dean Forest, 203; section of, near Bristol, 207; of Newent, 214; of Devonshire, 215
Coal, origin of, opinions respecting, 151; variable composition of beds of, 153; range of beds of, 155; roof of beds of, *ib.*; removal of upper surfaces of some coal beds by abrasion, 156; remarks respecting origin of, 179
Coal seams formed of drifted Sigillaria, 149
Coast, ancient, at the time of the new red sandstone, from the Quantock Hills to Tor Bay, 256
Coast, character of older rock at the poicilitic period from Tor Bay to North Wales, 265
Coast character of old red sandstone escarpments, near Brecon, 60
Coasts, rate of waste varies according to given conditions, 297
Cockshoot Rock, bed in the coal measures of South Wales so named, care required in identification of, 192
Coddon Hill grits, 136
Comminuted shells, sands formed of, 18
Conditions required for continuation of species from the time of Silurian rocks to that of the Devonian rocks, 96
Conducting power, difference of, as regards heat of certain rocks, near Builth, 34
Conglomerate of the poicilitic series from near Minehead to Thorn St. Margaret, Somerset, 256; probable origin of the limestone pebbles in, 257
Conglomerates, large size of rounded pieces of rock in, on the south of Helford River, Cornwall, 99; range of these conglomerates, *ib.*
Conglomerates, probable mode of formation of extensive flat beds of, in old red sandstone, 64
Conglomerates, proving that the Malvern sienites were formed prior to the Caradoc sandstone, 37
Connexion, difficulty of establishing between Petherwin and Plymouth groups of Devonian rocks, 87
Contortion of the older rocks in South Wales and South Western England, 221; of the Welsh coal measures, 223; of the older rocks between May Hill and the Mendips, 225
Contortions, diagram to explain effects of, between Chudleigh and Holme, Devon, 85
Contortions not produced by numerous small isolated efforts, 317
Conversion of carbonate of lime of corals, and shells into ordinary limestone, 18
Coral reefs, good examples of calcareous matter accumulated by animal means, 17
Coral reefs, resemblance of South Devon limestones to, 92
Couch, Messrs., discovery of Cornish organic remains, 102
Copper and tin raised in Cornwall, 510
Copper mining, early history of, 510
Copper ore, price of, from 1700, 512
Copper, oxide of, lamination of, 454
Copper raised in Cornwall, table of, 512
Copper, sulphate of, diamagnetic character of, 443
Corals and molluscs, ill suited conditions for existence of, amid deposits of the old red sandstone of Herefordshire, &c., 52
Corbula, pleistocene species of, 409
Coriocella, pleistocene species of, 430
Costar, Mr. John, introduced large waterwheels in Cornwall, 517
Crag, coralline, fossils of, 362; red, fossils of, 362; Norwich, fossils of, 363; living species in Crag, 386
Creatures, marine, lacustrine and fluviatile living among volcanic ashes and lapilli, 2
Cretaceous periods marked by depressions, 322
Creusia, pleistocene species of, 431
Croscombe, south of Mendips, section dolomitic limestone and new red sandstone of, 250
Crustacea, British marine, 355
Crystalline force overpowering magnetic power, 446
Crystallization, magnetic influence on, 445
Csetate, hill at Verespatak, 483
Cumberland copper mines, 510
Cupar, Fifeshire, basaltic dyke at, 477
Current, tidal, distance to which mechanically suspended matter is borne by, 16
Current voltaic, influence of, on clay, sandstone, and metals, 453
Currents, tidal, action of, on deposits, 10
Curvature and distortion of strata, 298
Cwm Twrch Mine, analysis of gas from, 477
Cypræa, pleistocene species of, 428
Cyprina, pleistocene species of, 413

D'Archiac, Vicomte, and De Verneuil, M., remarks on the Palæozoic fauna, 105
Dartmoor, granite of, thrust up, and cutting off and forcing aside Devonian rocks, 84
Darwin, Mr., on Moel Trefaen, 384; on the Gallapagos, 402
Davy, Sir Humphry, on the entombment of forests, 478
Dean, Forest of, an outlier of the Monmouthshire coal field, 303
Dean Forest, section of coal measures in, 203; supposed basin produced by movement of the beds, 223
De la Beche, Sir Henry, on the formation of the rocks of South Wales and South Western England, 1
De Luc, his view of the origin of coal, 151
Dentalium, pleistocene species of, 420
Denudations, the manner in which they are affected, 327
Denudations, their results exemplified in the present outline of the ground, 328

Deposit, contemporaneous volcanic and ordinary, 2
Deposits, diagonal partings in, 10
Deposits from the action or agency of water, 4
Deposits, variable kind and modification of, along the eastern shores of America, 19
Deposits. volcanic. rise of from beneath to above the level of the sea, 4
Depression of land and sea bottoms during New Red and Liassic periods. 321
Detritus, immediate discharge of, checked by tidal rivers, 16
Devonian rocks or system, 65; proposed by Professor Sedgwick and Sir R. Murchison, *ib.;* Mr. Longdale's researches respecting, *ib.;* lithological difference of from old red sandstone of Herefordshire, &c., 69; Linton group of the, 70; character of the organic remains of the Linton group, *ib.;* of the Ilfracombe group, 71; of the Pilton group, 75–78; of the Petherwin group, 79–81; range of the Petherwin group, 81; trappean ash beds in, 82; character of organic remains in Plymouth group, 94; general character of organic remains in Devonian rocks, 96; range of Plymouth group into Cornwall, 97; general remarks respecting, 103
Devonshire, coal measures of, 215
Diagrams of the British fauna and flora, explanation of, 404
Diallage rock of the Lizard, Cornwall, posterior to the serpentine, 101
Diamagnetic curve, meaning of, 436
Dickie, Dr., on the algæ of Aberdeen, 354
Dinas Head, north Pembrokeshire, contorted Silurian rocks of, 226
Disturbances at the close of the coal measure period, 314; altered conditions resulting therefrom, 315; thickness of disturbed strata, 316
Disturbances and unconformities of older strata in North Wales and its neighbourhood, 310; comparatively unfelt in South Wales, 311
Dolomitic conglomerate, resemblance of to a consolidated beach, 240; sections to illustrate the occurrence of, on the Mendips and near Bristol, 242; of Glamorganshire, 243; of Tortworth, 246; of vicinity of Bristol, *ib.;* of Portishead, 248; origin of cementing matter of, 251; variable age of, 252
Donax, pleistocene species of, 410
Dressing works at Schemnitz, 491
Drift, northern, its relations with the existing fauna and flora of the British Isles, 336
Dundry Hill, near Bristol, section of inferior oolite, lias, and new red sandstone series of, 255
Dunraven Castle, Glamorganshire, lias resting on disturbed carboniferous limestone near, 271
Duty of Cornish steam-engines, 518

Earth, magnetism of due to radiant forces, 458
Echinoderms, British, 361; fossil in drift, 431
Echinus, pleistocene species of, 431
Ecole des Mines, conductors of, 498
Ecton Hill, Staffordshire, 512
Education, necessity of educating miners, 485
Education, system of, at the Mining Academy, Schemnitz, 490
Edward III., grants given by, 510
Edward VI., grants by, 510
Effects of gentle disturbances, 311
Effects produced by violent flexures of strata, 317
Effects, volcanic, modification of beneath level of the sea, 3
Electricity of mineral lodes due to chemical decomposition, 456
Electricity, sources of, 455
Electro-chemical power of currents from mineral veins, 456
Elevated land, often tipped with hard rocks, 329
Elizabeth, grants by Queen, 510
Elvans of Cornwall and Devon, 234; their probable origin, 235
Emarginula, pleistocene species of, 422
English system of manufacturing malleable iron, 506
Equivalents in geological time, difficulty of establishing minute, 67
Eudiometrical processes described, 461
Eweston, Pembrokeshire, coal measures of, 158
Existing coasts, forms of referable to varied geological phenomena, 297
Export of French coal, 502

Faraday on electro-chemical decomposition, 457
Farewell Rock, or Millstone Grit, variable thickness of, 144
Fault, near Sully Island, Glamorganshire, 238; north of Bath, 239; of Meer, Wiltshire, *ib.;* of Wanstrow, *ib.*
Faults, older, observable in South Western England, 237; in the South Welsh coal measures, 238; different dates of, 239
Fauna, British, on the origin of, 336
Fish, conditions for the existence of, amid deposits of old red sandstone, 52
Fishes, of the British Seas, 354; of Boreal America, 382; fossil, 406
Fissurella, pleistocene species of, 421
Flora, of west of Ireland, 338; of Devonshire, *ib.;* of the Channel Isles, *ib.;* of the South-East of England, 339; of the chalk districts, *ib.;* of the British mountains, 440; of the Scandinavian Alps, *ib.;* of Norway, *ib.;* of Central and Western Europe, 341; origin of the British, 343; origin of Alpine floras, 345, 350, 351; of the Germanic flora, 352;

marine flora of Britain, 353, 373, 374; of the Azores and Madeira, 401
Forbes, Professor E., on the connexion between the distribution of the fauna and flora of the British Isles, and the Northern drift, 336
Forchhammer, Professor, on the Danish drift, 385
Forest marble, origin of, near Frome, Somerset, 285
Fossils of the pleistocene strata, catalogue of, 406
Fox, R. W., experiments of, 434
France, coal and lignite raised in, during 1844, *ib.*
France, iron and steel raised in, during 1844, 501
Freiberg in Saxony, college at, 486
Freshwater East, near Pembroke, section of junction of old red sandstone and Silurian works at, 54
Friction-marks or furrows, good example of, in the coal measures near Nolton Haven, 160
Fullers' earth, 292
Fusus, pleistocene species of, 424

Gases, analyses of, from Hebburn Pit; Wallsend gas; Jarrow, Bensham Seam; Hebburn Pit, Bensham Seam; Wallsend Pit, Bensham Seam; Wellgate Colliery, Jarrow five-quarter seam, Jarrow low main, 475
Gases evolved during the formation of coal, 460
Gases, method employed in collecting, *ib.*
Gateholm Island and Wooltack Park, Pembrokeshire, old red sandstone and Silurian rocks of, 27
Geislautern, mining school of, 497
Geological sections on a true scale, importance of, in geological reasonings, 298
Geology, useful applications of, 485
German forge steel, importation of into France, 508
Gogofau Mine, Carmarthenshire, 480
Gold ornaments discovered at Dolau Cothi, *ib.*
Gold, oxide of, diamagnetic character of, 444
Gould, Dr., on the North American Mollusca, 377
Graham, Professor, researches of, on the gases evolved from coal, 460
Granite of Cornwall and Devon, probable date of protrusion of, 228; common character of, 231; chemical composition of, 232; veins of, 234
Great Britain, coal imported into France from, 501
Griffith, Mr., his view of the strong resemblance of North Devonian rocks to the carboniferous slate and yellow sandstone of Ireland, 76
Griffith, Mr., researches of, in Devon, 141
Groups of islands, Irish and Welsh probably contemporaneous, 333
Gulf weed, history of, 349

Hamilton, Mr. C. W., Irish researches with reference to Devonian rocks, 141
Hanstein on Muschman's experiments, 435
Harptree, Mendip Hills, modification of lias near, 277
Harvey, Dr., his account of the gulf weed, 349; his researches on the British algæ, 354
Haynicher coal field, 489
Hebburn Colliery, gas from, 469, 470
Hebburn Pit, Bensham Seam, 472
Hematite iron, accumulation of, amid the carboniferous limestone of Dean Forest, 130
Henry VI., grants by, 510
Henry VIII., grants by, *ib.*
Hooker, Dr. Joseph, on Sargassum, 349; on Gallapagos flora, 402
Hornblende slate of the Lizard, Cornwall, metamorphic, 100
Horse-power in France, 505
Hot blast for smelting iron in France, 504
Huel, a Cornish term for Mine, 514
Huel Fortune steam-engine, 518
Huel Vor, first steam-engine erected at, 517
Humboldt, Baron Von, on the law of the distribution of Alpine floras, 351
Hunt, Robert, a notice of the copper and tin raised in Cornwall, 510
Hunt, Robert, experiments to illustrate the origin of clay ironstones in coal measures, 185; his suggestions respecting the origin of sulphuret of iron in coal, 188
Hunt, Robert, researches on the influence of magnetism and voltaic electricity on crystallization and other conditions of matter, 433
Hydraulic engine first introduced in Cornwall, 511
Hydrogen, determination of, in coal mine gas, 468

Ice, agency of, in transporting plants, 350
Igneous products, general character of, 1
Igneous rocks associated with the lower part of the poicilitic series in South Devon, 258; probable date of, 259
Igneous rocks, intermingling of, with detrital accumulations at Llanwrtyd, 31; at Builth, 32
Igneous rocks of Malvern probably in part out of water when neighbouring Caradoc sandstone was formed, 48; of Builth, in part also, the same, 49
Igneous rocks of Pembrokeshire, general character of, 229; variable composition, 230
Importation of coal in France, 502
Importation of copper into England early, 511
Inferior oolite, rests unconformably on the

carboniferous limestone of the Mendip Hills, 287; variable lithological character of, Mendip Hills, 291.
Ireland, botanical features of, 338; peculiarities of the zoology of, 342; southern fossils in drift of, 377
Ireland, early contortions of the older rocks in, felt in Pembrokeshire, 222
Iron in the soil, condition of, 478
Iron, peroxide of, in the new red sandstone series, 264
Iron, produce of, in Russia, Sweden, and Prussia, 502
Iron pyrites at Ogofau, 481
Iron, sulphuret of, in coal beds, origin of, 187
Ironstone clay, occurrence of, 185; origin of, 185; variable composition of, 186; various minerals found in the cracks in, 187
Iron works in France, 504
Irregular drift, example of in coal measures near Little Haven, Pembrokeshire, 160
Islands formed during oscillations of level, 330

James, Captain, R.E., discovery of copper mingled with plants in old red sandstone of Wexford, Ireland, 55
James, Captain, R.E., his researches on the Irish drift, 366, 377, 385
Jarrow, analysis of gas from, 471
Jarrow five-quarter seam, analysis of gas from, 474
Jarrow Low Main, analysis of gas from, 475
'Journal des Mines,' publication of, 497

Keswick, copper mine at, 510

Lacuna, pleistocene species of, 422
Lakes, variable kinds of deposits in, 7
Lamination produced by voltaic electricity, 451
Lamouroux, his observations on the distribution of marine plants, 353
Lampeter, Silurian rocks of, 25
Land at the period of Silurian rocks of South Wales, 49
Land and water, observations on distribution of, in South Wales and South-Western England at time of poicilitic series, 250
Land unabraded by the sea until a comparatively late period, 325
Lateral pressure, great, exerted against the older rocks of South Wales and adjoining parts of England, 224
Lead, diamagnetic character, 445
Lectures on mining in Saxony, 488
Leda, pleistocene species of, 417
Liebig, view of, relative to carburetted hydrogen, 476
Lias, boundary of, in Somerset and Devon, when the upper green sand was deposited, 279
Lias, changes in the lithological character of, in Somerset, 276
Lias, conditions under which it was formed in South Wales and South-western England, 281
Lias, conglomerates of, 269; mode of occurrence of, in Glamorganshire, 269
Lias, resemblance of, lithologically, to carboniferous limestone in some parts of Glamorganshire, 272; gradual covering up of subjacent inequalities of older rocks by, 273; rests unconformably on carboniferous limestone, near Cowbridge, Glamorganshire, 274; upper, near Gloucester, 275
Limestone, decomposition of surface of, 251
Limestone, local formation of, in lower Silurian rocks of South Wales, 30
Linnæus, on the Uddevalla fossils, 363
Lithological character of beds beneath coal, 148
Littorina, pleistocene species of, 422
Llandilo, Silurian rocks of, 24
Llanelly, Caermarthenshire, coal measures of, probably the highest of the South Welsh series, 199
Llangadoc, Caermarthenshire, Silurian rocks of, 23
Local character of new red conglomerate in South Wales and South Western England, 264
Logan, Mr., presentation of labours in Glamorgan and Caermarthenshire to the Geological Survey by, Stigmaria beds pointed out as very constantly found beneath those of coal, 145; upright stems of Sigillariæ discovered by, 184; beds of coal pebbles in coal measures pointed out by, 193
Lottia, pleistocene species of, 421
Lucina, pleistocene species of, 411
Ludlow rocks, modification and range of from Malvern into South Wales, 42; large concretionary condition of, 43; probable considerable difference of thickness is caused by overlap, 44; great thickness of, near Builth, 46
Lutraria, pleistocene species of, 409
Lyell, Mr., his notice of stigmaria beds beneath in America, 147; on the North American meiocene, 349; on the rise of land in Sweden, 365; on the former existence of the spruce in Britain, 395; on Bridlington beds, 392
Lyme Regis, lias of, 280

MacAndrew, Mr., his observations on the distribution of British marine animals, 369, 389
Machines, steam and hydraulic, employed at the mines in France, 505
Mactra, pleistocene species of, 408
Magnesian conglomerates of the new red sandstone, ancient beaches, 318; height of ancient land determined thereby, *ib.*

Magnetic curve defined, 436
Magnetism and electricity, relation of influence, 458
Magnetism, influence of on crystallisation, 433
Malleable iron, manufacture of, 506
Mallotus villosus, 406
Malvern, Silurian rocks of, 20
Mammalia, marine British species, 354; not found in Ireland, 342; of Boreal America, 397; pleistocene, 395, 406; extinct tertiary, of Britain, 395, 406
Mammaliferous crag, fossils of, 391
Man, Isle of, tertiaries of the, 394
Margarita, pleistocene species of, 430
Marine animals, horizontal distribution of, 361; distribution in depth, 371
Marloes Bay, Pembrokeshire, Silurian rocks and old red sandstone of, 26
Marls, red and blue, of poicilitic series, analysis of, 254
Marlstone, of the lias, 275
Matter, chemical solution of, in springs, 4; removed in chemical solution from one locality to another, 5; mechanical removal of, by rivers, 6; two modes of mechanically transporting, by water, 6; detrital, deposit of in tideless seas, 8; mechanical suspension according to density of fluid, 10; mass and kind of, required for the formation of the Silurian rocks, 47; composing old red sandstone of Herefordshire, and whence derived, 65; the great amount of, removed from above the present surface, 304; instances of the, removed from the Woolhope district, *ib.*; from the Mendip Hills and Bristol, 305; from South Welsh coal-field, *ib.*; from Pembrokeshire, 306; from between Caermarthenshire and Llangadoc, 307; from on the north-east of Llandovery, 308; from between Cefn Crib and Dean Forest, 309; the amount of, necessary to form the older rocks of South Wales and its neighbourhood, and from whence derived, 334
May Hill, Silurian rocks of, 22
Mediterranean flora, 350, 401
Megaceros or Irish elk, position of, in tertiary beds, 394
Mendip Hills, carboniferous limestone of, 127; coal measures near, 213; observations of coal measures which may occur on south and west of, 213; great lines of undulating beds in, 225
Mercury, repelled by magnetism, 439; protosalts of, under the influence of magnetism, 440, 441
Metalliferous veins of Saxony, 489
Metamorphic rocks near Builth, 34
Metamorphic rocks of Devon and Cornwall near granite, 233
Mica, lithia, in Cornish granites, 231
Milford Haven, its analogy to certain valleys, 329
Mineral fuel, produce of, in France, 501
Mineral lode, artificial, 452
Mineral veins, electricity of, 455
Miners' school of Alais, 500
Mines, copper, average produce of, 514
Mining academies of Saxony and Hungary, 485
Mining establishment of France, 495
Mine workings, ancient, at Gogofau
Miocene tertiaries, 348, 400
Mitra, pleistocene species of, 428
Mollusca, British, distribution of, 356; of the British Channel, 357; South British, type of, 357; European, type of, *ib.*; Celtic, 358; British, *ib.*; Atlantic, 359; Oceanic, *ib.*; Boreal, *ib.*; Arctic, 360; American, 380
Molluscs, boring, surfaces of carboniferous limestone acted on by, in the Mendip Hills, at the time of the inferior oolite, 289; surfaces of lias conglomerate acted on, 290; surfaces of successive beds of inferior oolite acted on by, 291
Montacuta, pleistocene species of, 409
Murchison, Sir R., value of labours on Silurian rocks, 50; on the northern drift, 384; on extinct mammalia, 397
Murex, pleistocene species of, 423
Muschman on influence of magnetism, 435
Mya, pleistocene species of, 407
Mytilus, pleistocene species of, 419

Nassa, pleistocene species of, 427
Natica, pleistocene species of, 429
Necessity of properly weighing condition under which animal and vegetable life has existed in application of zoological and botanical evidence to the determination of the age of rocks, 67
Newent, coal measures of, 214
Newgale Sands, Pembrokeshire, section of coal measures at, 158
New red sandstone series, 239; common character of, from Tortworth to the Mendips, 255; organic remains in, 268
New red sandstone and tertiary times, climates between, 324
New red sandstone series, range and composition of, from Newham to the Malvern Hills, 262; common character of higher parts of, in South-western England and Wales, 267
Nitrogen, determination of, in coal gas, 467
Nodules formed along the line of the voltaic current, 453
Nolton and Druson Haven, Pembrokeshire, coal measures of, 159
North Pole, influence of, on metals, 449
Nucula, pleistocene species of, 417

Oakwell Gate colliery, analysis of gas from, 473
Ogofau mine, Carmarthenshire, 480
Old red sandstone, difficulty of clearly defining separation of, from Silurian rocks, 46; general character of, 50; unbroken exposed surface occupied by, in Shrop-

shire, &c., 51; cubic mass of, in the same county, *ib.*; red deposits, formation of, at the present time, 50
Old red sandstone, organic remains in, 51; cornstones of, 52; green and blue bands in, probable cause of, 53
Old red sandstone, plants mingled with carbonate of copper in, Wexford, Ireland, 55
Old red sandstone, section of, with lower part of the carboniferous limestone, in South Pembrokeshire, 61; section of upper part of, with lower part of carboniferous limestone, at Caldy Island, Pembrokeshire, 62
Old red sandstone, section of, with lower part of carboniferous limestone and upper part of Silurian rocks, between Dean Forest and Much Marcle, 55
Old red sandstone, thickness of, near Ross, Herefordshire, 57; probable mode of deposit of, 58; great arch of, near Cardiff, 59
Olefiant gas, determination of, in coal gas, 465
Oolitic epochs marked by progressive elevation, 321
Oolitic series, 269; manufacture of lower members of, near the Mendip Hills, 280
Ore mountains near Freiberg, 489
Organic remains of Cornwall long unknown, 101; recent researches have shown them somewhat common, 102
Organic remains, general character of, in Devonian rocks, 96
Organic remains in the new red sandstone series, 268
Ostrea, pleistocene species of, 420
Overlap of old red sandstone in Caermarthenshire and Pembrokeshire, 24
Overlap of old red sandstone in South Wales connected with the great movement of Silurian rocks anterior to the deposit of old red sandstone in Ireland, 60; of the upper beds of the old red sandstone over its lower beds in South Wales, *ib.*
Owen, Professor, on British fossil mammalia, 394
Oxygen gas, determination of, in coal gas, 465
Oysters, fossil, of the date of the inferior oolite, still adhering to surfaces of carboniferous limestone in the Mendip Hills, 289

Panopæa, pleistocene species of, 407
Paris Mountain, Anglesea, 510
Paris, plaster of, lamination of, 453
Patches of Silurian rocks in Pembrokeshire, 25
Patella, pleistocene species of, 421
Peach, Mr., labours of, on Cornish organic remains, 102
Pebbles of coal, beds containing, in the coal measures of South Wales, 193
Pecten, pleistocene species of, 419
Pectunculus, pleistocene species of, 416
Pembrokeshire, coal measures of, 158–168
Pembrokeshire, granite of, 230
Penarth Cliff, Cardiff, section of new red marls and lias at, 253
Pennant grit, of Bristol coal measures, equivalents of, in South Wales and Monmouthshire, 192
Pesey, in Savoy, mining establishment at, 497
Petherwin group, passage of into the carbonaceous series, 138
Phillippi, Dr., on the mollusca of Sicily, 378
Phillips, Professor John, remarks respecting identification of rocks by organic remains, 67; lists of Devonian fossils in Linton group, 70; Ilfracombe group, 71; Pilton group, 73; Petherwin group, 80; carbonaceous group, 140; action of boring molluscs at the time of the inferior oolite on the carboniferous limestone of the Mendip Hills, observed by, 289; on the association of extinct mammalia with existing fresh-water shells in Yorkshire, 395
Pholas, pleistocene species of, 407
Physical features of the interior of a country, from whence derived, 298
Pig iron produced in France, 502
Plants, diffusion of, 347; distribution of Alpine, 351; of marine, 353; of littoral marine, 373; of deep-sea species, 374; of the Mediterranean, 401
Plants, fossil, of the lias, whence derived, 284
Platinum, chloride of, and nitrate of potash, neutral character of, 444
Platinum, oxide of, magnetic character of, *ib.*
Playfair, Lyon, on the gases evolved during the formation of coal, 460
Pleistocene beds of Britain, 366; fossils found in them, 367; Wexford beds, 377; catalogue of marine fossils in, 406
Pleistocene, relations of the, 403
Pleurotoma, pleistocene species of, 426
Pliny on the gold-mining of the Romans, 483
Plumbiferous character of various rocks near Dunraven Castle, Glamorganshire, 273
Poder, or mundic, 511
Poicilitic series, 239; thickness of in South Devon and West Somerset, 260; general view of origin of in South-western England and South Wales, 265
Poles, magnetic, dissimilar action of, 448
Position, highly inclined, of masses of strata evidences their original more extended prolongation, 303
Professors at the Freiberg Mining Academy, 487
Professors at the Mining Academy of Schemnitz, 491

Psammobia, pleistocene species of, 410
Pumice, of the date of the Devonian rocks, near Trecarrell Bridge, 84
Purpura, pleistocene species of, 427
Pyrites, copper, decomposition of, 457

Quintal, price of iron per, 503

Radiata, British marine, 360; fossil, 431
Ramsay, Andrew, on the denudation of South Wales,
Ransome and Cooper, Messrs., analysis of red and blue marls by, 254
Red conglomerates and sandstones of the upper part of the Silurian rocks near Llangadoc, 46
Red sandstone in South Devonian rocks, 89
Reeks, Mr. Trenham, analysis of dolomitic Silurian limestone by, 39; analysis of marls of old red sandstone series by, 55
Reptiles, British, their distribution, 344
Restoration of disjointed strata, &c., 299
Restoration of sections, the manner of, 300
Richardson and Regnault, formulæ of, 476
Richardson, Sir John, on North American zoology, 382
Ripple-marks, formation of by friction, 11; depth at which they may be produced, 16
Rissoa, pleistocene species of, 423
Ritter, experiments of, 448
River, tidal, greatest scouring effect in, 15; filling up of, *ib.*; backward and forward motion of mechanically suspended detritus in, *ib.*
Rocks, modification of, from flow of heated and molten matter over them, 5
Rocks, on the formation of, in South Wales and South-western England, 1
Romans probably worked Gogofau for gold, 480
Rules of the Mining Academy of Saxony, 487

Sanders, Mr. William, his excellent geological map of the country near Bristol, and the presentation of his labours to the Geological Survey, 126; section of Aust Cliff by, 253
Sands of inferior oolite, mode of occurrence of, near the Mendip Hills, 286
Sandstone, curious block of, for breaking ore at Gogofau, 483
Sandstones, decomposition and removal of, by chemical and mechanical means, 6
Sandstones of the Foreland, Morthoe and Pickwell Downs, North Devon, resemble old red sandstone of Monmouthshire, &c., 72
Sargassum Bank, its probable origin, 349
Saurians, of the time of the lias, inhabited the ancient shores of the Mendips, 283
Savery's steam-engine, 517
Saxicava, pleistocene species of, 410
Scalaria, pleistocene species of, 423
Schemnitz, in Hungary, college at, 486
School of Mines of Paris, 497
Schouw, Professor, his botanical regions, 352, 396
Scrobicularia, pleistocene species of, 409.
Sea, distribution of detrital matter in, 7
Seas, cretaceous. part of their margin, 323
Sections, comparison of Silurian rocks in, from the Malvern district to Pembrokeshire, 28
Sedgwick, Professor, and Sir R. Murchison, proposed Devonian system, 65; inferences of, respecting connection of North and South Devon rocks, 94; coal measures of Devon pointed out by, 139, 215
Sedimentary strata derived from the waste of pre-existing rocks, 297
Serpentine of Cornwall, its probable date of eruption, 100; metamorphic changes produced by, *ib.*
Shepton Mallet, mode of occurrence and variable lithological character of lias near, 278
Shingles, travelling of, 12; modification of, 13
Sicily, tertiaries of, 378
Sigillariæ and *Lepidodendra*, confused drifts of, in the coal measures of South Wales, 193
Sigillariæ, upright stems of, in coal measures, 183
Silurian rocks, 20
Silurian rocks, general view of lower, from Malvern to Pembrokeshire, 29
Silver and iron, mutual influence of magnetism on, 442
Silver, precipitated, influence of magnetism on it, 438
Smith, Mr., of Jordan Hill, his researches on the pleistocene fossils, 363, 365, 398; on the geology of Madeira, 401
Smyth, W. Warington, on the Gogofau, or Ogofau, mine, 480; on the mining academies of Saxony and Hungary, 485
Society for mineral and battery works, 511
Solen, pleistocene species of, 407
South Devon limestones, care required in connecting them with each other, 89
South Devonian rocks, character of between the Tamar and Teign, 91
South Pole, influence of, on gas, 449
South Wales and South-western England, variable character of accumulations in, from the Silurian deposits to those of the lower part of the oolitic series, inclusive, 292
South Wales, physical structure of, between the new red sandstone and tertiary times, 323
Spain, plants of, in Ireland, 338
Specific centres, doctrine of, 336
St. Austell, Cornwall, granite of, 231
St. Bride's Bay, Pembrokeshire, 329
Steam-engine, improvement of, in Cornwall, 517
Steam-engines, duty of, 518
Steam power in France, 505
Steel manufacture in France, 507

Steinhauer, Mr., his account of stigmaria beds, 147
Stigmaria (*ficoides*), opinions respecting it, 149
Stigmaria (*ficoides*) beds found very constantly beneath those of coal, 145; various names given to those beds, 146; other fossil plants found in, 151
Strabo, his classification of islands, 401
Strata consolidated previous to disturbance, 316
Strata often saved from denudation by the accident of position, 331
Study, course of, at School of Mines, 497
Sub-aërial volcanos at time of Llandilo flag deposits in South Wales, 31
Submergencies and oscillations of Wales, &c., during tertiary times, and their effects, 326
Subsidence of land, effect of, at the poicilitic period, between South Wales and Devon, 266
Sulphate of copper, crystallizing under magnetic influence, 447
Sulphate of iron, crystallizing under magnetic influence, 447
Sulphuret of copper, decomposition of, 456
Surface drift, its composition and extent, 325
Suspension of chemical action by magnetic force, 455
Sutton stone, 272

Tables, of the distribution of testacea in the northern hemisphere, 367; of the reptiles of Britain and Belgium, 344; of regions of depth in the British Seas, 375; of mollusca common to North America and Europe, 380; of pleistocene fossils, 406
Talco-micaceous slates of the Lizard, Cornwall, probably metamorphic, 101
Tellina, pleistocene species of, 410
Terebratula, pleistocene species of, 406
Tertiary epochs, elevation renewed in, 323
Testacea, distribution of British marine species, 356–371; of the Mediterranean, 367; of Massachusetts, *ib.*; of Greenland, *ib.*; of the British pleistocene, *ib.*; littoral species of, 370; distribution in regions of depth, 375; of Europe and North America compared, 380; fossil pleistocene species, 406
Theresa, Maria, Empress, establishes Mining Academy at Schemnitz, 489
Thompson, Mr. William, his researches on the Irish fauna, 344, 357
Thracia, pleistocene species of, 409
Ticketings in Cornwall, 513
Tidal seas, deposits in, 10
Tides, action of, tendency to flatten out sedimentary deposits, 11
Tides, smoothing action of, on deposits, 16
Time occupied in their accumulation compared to that of the latter denudations, 335
Tin, iodide of, diamagnetic character of, 443
Tin, muriate of, diamagnetic character of, 443
Tin raised in Cornwall, 510
Tornatella, pleistocene species of, 428
Town Hill Sandstones, Swansea, section of, 193
Tradition of caves at Gogofau, 483
Trappean ash, care required in properly distinguishing it from greenstone, 33
Trees, roots of, necessities of, 478
Trichotropis, pleistocene species of, 428
Trimmer, Mr. Joshua, on the fossils of Moel Trefaen, 366, 384; on the Bramerton Crag, 393
Trochus, pleistocene species of, 430
Tubulipora, pleistocene species of, 432
Turritella, pleistocene species of, 423
Types of vegetation in the British Isles, Asturian, 338, 347; Norman, *ib.*; Kentish, 339, 346; Norwegian, 340, 344; Germanic, 341, 343

Uddevalla, in Sweden, fossils of, 361
Unconformities of strata, when small, inappreciable after subsequent great disturbances. 312
Underclay, analysis of, 479
Uske, Silurian Rocks of, 22

Vale of Towy, Caermarthenshire, anticlinal axis of, 329
Vallis Vale, Frome, unconformable position of, inferior oolite upon carboniferous limestone at, 287
Vegetable fuel in France, consumption of, 504
Vegetable matter, conversion of into coal, * 219
Vegetable matter in the lower Silurian rocks, from Malvern to Pembrokeshire, 35
Vegetation, ancient, how destroyed, 479
Velutina, pleistocene species of, 422
Venus, pleistocene species of, 414
Volcanic action contemporaneous with the deposit of the older Silurian rocks of Builth, 33; of Malvern, 35
Volcanic ash of Devonian period, organic remains, 90
Volcanic cones, 2
Volcanic products, ancient, complicated mixture of detrital accumulation with, in Devonian rocks, between Petherwin and Dartmoor, 83
Voltaic electricity, influence of, on conditions of matter, 450
Von Buch, Baron, his observations on the pleistocene beds, 365

Wallsend gas, analysis of, 471
Wallsend Pit, Bensham seam, 473
Warburton, Mr., notices of magnesian or dolomitic conglomerate of Bristol and the Mendips, 239

Waste effected by the sea of the new red sandstone, 320
Watson, Mr. Hewett Cottrell, his researches on the distribution of British plants, 342, *et ante.*
Wave, tidal, action of on sea bottoms and estuaries, 10
Weaver, Mr., his notice of fireclay bed beneath Kilkenny coal, 147
Wenlock limestone, variable thickness and mode of occurrence of, 39; area occupied by, *ib.*; change of from argillaceous to an arenaceous condition westward, in South Wales, 41
Wenlock shales, range, variable thickness, and mineral modifications of, from Malvern into South Wales, 38
Westbury on Severn, section of lias and new red marls at, 261
Westleigh, organic remains in limestones of, 136
Whales of, ancient and modern ranges of, 396
Winds, prevalent, action of breakers caused by, 13
Woody fibre, changes of, 460
Wood, Mr. Searles, his researches on the fossils of the crag, 362, 391
Woolhope, Silurian rocks of, 21

Zetland, fishing banks of, 399
Zinc, diamagnetic character, 445
Zinc, oxide of, lamination of, 454
Zones of depth, 370; littoral, 371; laminarian, 372; of Corallines, 374; of deep-sea corals, 374
Zoophytes, British, 360; fossil drift, 432

END OF VOLUME I.

LIST

OF

GEOLOGICAL MAPS AND SECTIONS,

PUBLISHED BY MESSRS. LONGMAN AND CO.

FOR HER MAJESTY'S STATIONERY OFFICE.

[THESE Maps consist of the Maps of the Ordnance Survey, Geologically Surveyed and Coloured by the Geological Survey of Great Britain, by the Authority of Her Majesty's Government, under the Superintendence of Sir HENRY DE LA BECHE, Director-General of the Geological Surveys of the United Kingdom. The various Formations are distinctly traced and coloured in all their Geological Subdivisions.]

The Counties of which the Geological Survey is completed are—

CORNWALL, including Sheets 24, 25, 26, 29, 30, 31, 32, and 33. Price, in Sheets, 3*l.* 9*s.*

DEVONSHIRE, including Sheets 20, 21, 22, 23, 24, 25, 26, 27, and 29. Price, in Sheets, 4*l.* 2*s.*

The Geology of the above two Counties is amply illustrated by Sir H. De la Beche's Report. 1 vol. 8vo. 14*s.*

GLAMORGANSHIRE, including Sheets 20, 36, 37, 41, and 42, (SE. & SW.) Price, in Sheets, 3*l.* 1*s.*

Horizontal Sections, 14*s.*; and Vertical Sections, 25*s.*; illustrate the above.

MONMOUTHSHIRE, including Sheets 35, 36, 42 (SE. & NE.), and 43, (SW.) Price, in Sheets, 2*l.* 6*s.*

Horizontal Sections, 7*s.*; and Vertical Sections, 5*s.*; illustrate the above.

*** For particulars, *see* the detailed List of the separate Sheets, as follows:—

19. Half of Somerset, and part of West Wilts; illustrating the Geology of the Mendip Hills and the Somerset Coal Fields, and the Oolitic and Chalk deposits on the East, &c. 16*s.* 6*d.*

Horizontal Sections, sheets 14, 15, 16, and 17, 28*s.*; and Vertical Sections, sheets 11 and 12, 10*s.*; illustrate the above.

20. West Somerset and part of South Glamorgan. It shows the continuation of the Carboniferous Limestone of the Mendips across Bleadon Hill to the Bristol Channel, marks the bounds of the Lias, New Red Sandstone, and Devonian Rocks in Somerset, of the Lias and Carboniferous Limestone in Glamorgan, &c. 8*s.* 6*d.*

Horizontal Section, sheet 11, 7*s.* illustrates the above.

21. SW. Somerset, NE. Devon, and part of West Dorset. It exhibits, in the West, the continuation of the Devonian Rocks to the South of Dulverton and Wiveliscombe, the Coal Measures, the New Red Sandstone, with its Dolomitic Conglomerate, and Igneous Rocks near Crediton and Silverton. On the East the Inferior Oolite, Lias, Upper Greensand, and Chalk. 16*s.*

22. Part of SE. Devon. The Coast-line from Lyme Regis to Torbay. The continuation of the Coal Measures of sheet 21 round the East part of the Granite of Dartmoor, the Devonian Rocks thence to Torbay, with the mode of occurrence of all the Limestones; the New Red Sandstone, and Upper Greensand, between Exeter, Torbay, and Lyme Regis; the Lias of Lyme Regis; and the Bovey Lignite and Clay; the Elvans, &c. 10*s.*

23. Devon between Torbay and Start Point. Shows the continuation of the Devonian Rocks, and Chlorite Slates, &c. at South end of Start Bay. 4*s.*

24. Part of South Devon and of Cornwall. It exhibits the continuation of the Chlorite Slates, &c. from Start Bay to Bolt Tail; the rest is principally composed of the Devonian Rocks, with their associated Igneous Rocks and Limestones. 6*s.* 6*d.*

25. SW. Devon and East Cornwall. Comprehends the Granitic District of Dartmoor Forest, and the Granite of Brown Willy, between Alternan and St. Cleer. It explains the arrangement of the Devonian Strata and Coal Measures encircling these rocks, with all the bands of Limestone and Elvans. The Mineral Veins and the distribution of Stream Tin, are delineated. 16*s*.

26. West Devon and NE. Cornwall; showing the continuation of the Devonian Rocks towards Bideford Bay; the Coal Measures; and the New Red Sandstone to the East of Hatherleigh, &c. 12*s*.

27. Devonian Rocks, with a small portion of Coal Measures near Barnstaple. 5*s*. 6*d*.

28. Lundy Island. Granite. 3s. 6d.

29. The North of Cornwall, showing the Coast-line from Hartland Quay to Cambeak. Coal Measures, being a continuation of those illustrated in sheets 26 and 30. 3*s*. 6*d*.

30. Part of Cornwall. Comprehending almost all the Granitic Districts of Brown Willy, Lostwithiel, and St. Austell. The Elvans are traced. The remainder is Devonian, with a small portion of Coal Measures on the NE. The Mineral Veins and distribution of Stream Tin are delineated. 9*s*. 6*d*.

31. Part of Cornwall. Exhibiting the Southern half of the Granite near St. Austell, and most of that to the West of Falmouth; part of the Hornblende Slate, Serpentine, and Diallage Rock, between Helford River and Lizard Head. The rest is Devonian. The Mineral Veins, &c. are delineated. 10*s*. 6*d*.

32. Part of Cornwall. A continuation of the Hornblende Slate, Diallage Rock, and Serpentine, mentioned in Sheet 31. 4*s*.

33. Part of Cornwall. The Granite of Land's End, Elvans, &c., and the Devonian Rocks, as forming, together, the Mineral Districts of St. Just and Marazion. The Mineral Veins and Stream Tin are delineated. 7*s*.

35. Western Gloucester, the SE. of Monmouth, part of North Somerset and West Wilts; illustrating the Bristol Coal Field and the South part of that of the Forest of Dean; the Lias, New Red Sandstone, Carboniferous Limestone, Old Red Sandstone, and Silurian Rocks, between Usk, Bristol, and Pyrton Passage; and on the East, the Lias and Oolites, in all their sub-divisions, as high as the Forest Marble, six miles to the North of Dursley. 15*s*.

Horizontal Sections, sheets 12, 14, 15, 17, 28*s*.; and Vertical Sections, sheets 7, 11, 12, 15*s*.; illustrate the above.

36. The greater part of Glamorgan on the West, and Monmouth on the East, valuable, as it contains a part of the Monmouth and Glamorgan Coal Field. The Outcrops of the Coal Beds, the Faults, &c. are delineated. The Silurian District of Usk, and the Old Red Sandstone, Carboniferous Limestone, New Red and Lias Deposits, thence to the Bristol Channel near Cardiff and Bridgend. 19*s*.

Horizontal Sections, sheets 10, 11, 12, 21*s*.; and Vertical Sections, sheets 4, 7, 8, 9, 10, 25*s*.; illustrate the above.

37. West Glamorgan and South Carmarthen, continuing the Coal Field of Sheet 36 to Kidwelly: the Carboniferous Limestone and Old Red Sandstone of Gower. 11*s*.

Horizontal Sections, sheets 7, 8, 9, 21*s*.; and Vertical Sections, sheets 1, 2, 3, 4, 6, 25*s*.; illustrate the above.

38. South Pembroke. The SE. part of the Coal Field to Gillman Point. The Faults, and Outcrop of Coal Beds are traced. The remainder, South and West of Tenby, and the neighbourhood of Laurenny, shows the distribution of Silurian, Old Red Sandstone, Carboniferous Limestone, and Igneous Rocks. 6*s*.

Horizontal Sections, sheets 1, 2, 14*s*.; and Vertical Sections, sheets 5, 12, 13, 15*s*.; illustrate the above.

39. Small's Light, Pembroke; Bishop and his Clerks. 3*s*. 6*d*.

40. North Pembroke and West Carmarthen, continues the Pembroke Coal Field west to St. Bride's Bay. The Carboniferous Limestone, Old Red Sandstone, and Silurian and Igneous Rocks, further North. 13*s*.

Horizontal Sections, sheets 1, 2, 14*s*.; and Vertical Section, sheet 13, 5*s*.; illustrate the above.

41. Contains most of Carmarthen, parts of North Glamorgan, South Cardigan, and East Pembroke. The Southern part shows the Carmarthen Coal Field, from near Kidwelly to the neighbourhood of the Carmarthen Vans. To the North are the Carboniferous Limestone, Old Red Sandstone, and Silurian Rocks in detail. 14*s*.

Horizontal Section, sheets 2, 3, 4, 7, 8, 9, 42*s*.; and Vertical Section, sheets 3, 4, 5, 13, 14, 25*s*.; illustrate the above.

42. NW. West Brecknock and part of East Carmarthen, continuing the Old Red Sandstone to the North, and including part of the Silurians of Carmarthen and Brecknock. 3*s*. 6*d*.

Horizontal Section, sheet 4, 7*s*. illustrates the above.

42. NE. Part of East Brecknock and West Hereford. Old Red Sandstone. 3s. 6d.

Horizontal Section, sheet 5, 7s. illustrates the above.

42. SW. The SW. of Brecknock, part of North Glamorgan and East Carmarthen, marking the Northern bounds of part of the Coal Field, also the Carboniferous Limestone and Old Red Sandstone. 4s.

Horizontal Section, sheet 11, 7s.; and Vertical Sections sheets 8, 9, 10, 15s.; illustrate the above.

42. SE. Completes the NE. of the Glamorgan and Monmouth Coal Field, with the Coal Crops, Faults, &c. in detail. The Boundaries of the Carboniferous Limestone and Old Red Sandstone. 4s. 6d.

Vertical Sections, sheets 8, 9, 10, 12, 20s, illustrate the above.

43. NW. The Old Red Sandstone, and part of the Silurian Strata of Woolhope. 3s. 6d.

Horizontal Section, sheet 13, 7s.; and Vertical Section, sheet 15, 5s.; illustrate the above.

43. NE. Completes the Silurian District of Woolhope, with the Malvern Country as far North as the Wych. 3s. 6d.

Horizontal Section, sheet 13, 7s.; and Vertical Section, sheet 15, 5s.; illustrate the above.

43. SW. The West of Dean Forest Coal Field, with the Carb. Limestone and Old Red Sandstone around Monmouth. 4s.

Horizontal Section, sheet 12, 7s.; and Vertical Section, sheet 7, 5s.; illustrate the above.

43. SE. The greater part of Dean Forest Coal Field, the Carboniferous Limestone and Old Red Sandstone, the Silurian Rocks (Limestone, &c.) of Huntley and May Hill, and the New Red Sandstone and Lias on the banks of the Severn. 4s.

Horizontal Sections, sheets, 12, 13, 15, 21s.; and Vertical Sections, sheets 7, 12, 15, 15s.; illustrate the above.

INDEX to the Colours and Signs employed in the Geological Survey of Great Britain for South-Western England and Wales, 8s.

LIST OF HORIZONTAL SECTIONS,

CONSTRUCTED BY THE GEOLOGICAL SURVEY OF GREAT BRITAIN,

Illustrative of the Survey's Geological Maps.

These Sections are drawn to a scale of six inches to a mile, horizontally and vertically, and describe in detail the Geology of the Country over which they are drawn. Descriptions are engraved on each plate, thus rendering each Section a concise Report of the district it traverses.

The size of each plate is 3 ft. 3 in. by 2 ft. 3 in. They are engraved on Copper by Mr. Lowry, and coloured in accordance with the Maps. Price 7s. each.

Sheet I. Illustrates Maps 38 and 40.

Sect. 1. From St. Bride's Bay, near Solva, Pembroke, to the North Cliff of Ynys-y-Barry.—Sect. 2. Across Pembroke, from St. Govan's Head to Dinas Head, near Fishguard.

Sheet II. Illustrates Maps 38, 40, and 41.

Sect. 1. From the Sea, near Tenby, through Sandersfoot, to Landewi Velfrey, Pembroke; (Vertical Section 13 illustrates this Sect.)—Sect. 2. From near Cil-rhiw through Lampeter, Velfrey, and Panteg, to near Hendre, Pembroke.—Sect. 3. Through Pant Yiar and Clog-y-Fran, Carmarthen; (Vertical Section 13 illustrates this Sect.)—Sect. 4. From Laugharne, to the River Dewifawr, Carmarthen.—Sect. 5. From Maes Gwrda to Mydrim, Carmarthen; (Vertical Section 13 illustrates this Sect.)—Sect. 6. Across the Traps and Conglomerates of Pen-y-Moelfre, SW. of Carmarthen.

Sheet III. Illustrates Map 41.

Sect. 1. From Cerrig-dwfn to Mynydd-banc-y-ffair.—Sect. 2. From near Llandibie to Llangathen.—Sect. 3. From the Black Mountain, near Llangadoc, to Cefn-llwynhir, Carmarthen; (Vertical Section 14 illustrates this and the preceding Sections).

Sheet IV. Illustrates Maps 41, 42 NW., 57, and 58.

Section from the Old Red Sandstone, Mynyddbwlch-y-groes, Brecknock, to Craig-ddu, Cardigan Bay, between Aber-arth and Llansantffraid.

Sheets V. and VI. Illustrate Maps 42 NE., 56, and 57.

Sect. 1. Across the Old Red Sandstone and Silurian Rocks, from the Black Mountain Range SE. of Glasbury, to Allt-wen, Cardigan Bay, near Aberystwyth—Sect. 2. Across the Silurian Rocks, from Gwaun Ceste to Rhiw Gwraidd, Radnor.

Sheet VII. Illustrates Maps 37 and 41.

Sect. 1. Across the Coal Field of South Wales, from the Mountain Limestone, near Mynydd Garreg, by Pembray, to the Mountain Limestone, near Spritsail Tor, Llanmadoc, Gower; (Vertical Section 1 illustrates this Section).—Sect. 2. On the North Crop of the South Welsh Coal Field, from Brondyne Hill, by Pont Yates, to the Mountain Limestone near Yr Hengoed, Carmarthen; (Vertical Section 3 illustrates this Sect.) —Sect. 3. From Pen-clawdd, across Cefn-y-bryn, to Oxwich Point, Gower; (Vertical Section 2 illustrates this Sect.)

Sheet VIII. Illustrates Maps 37 and 41.

Section across the Coal Measures of Carmarthen, and Glamorgan, from the Carb. Limestone on the North of Cottage Hall, to the Sea in Caswell Bay.

Sheet IX. Illustrates Maps 37 and 41.

Sect. 1. Across the South Welsh Coal Field, from Craig and Cefn Drim, to Caswell Bay, Gower. Vertical Section 6 illustrates this Sect.)—Sect. 2. From Cilfay Hill, Swansea, to Castell Craig Cennen, on the North Crop of the Mountain Limestone.

Sheet X. Illustrates Map 36.

Sect. 1. Across part of the Coal Field of Glamorgan, from near Bryn Cethin Uchaf, by Mynydd Llangeinor to Blaen Afon.—Sect. 2. Across part of the Coal Field of Glamorgan, from Mynydd Moel Geulau to Mynydd Llandyfodwg.—Sect. 3. Across part of the Coal Field of Glamorgan, from the Ogmore, near Bryn Menyn, to Blaen Afon; (Vertical Section 7 illustrates the above three Sections).—Sect. 4. Coal Measures of Glamorgan from Trecastle to the Rhondda.

Sheet XI. Illustrates Maps 20, 36, and 42 SW.

Section near the Bendrick Rock, near Barry Island, Glamorgan, to Allt Llwyd, Brecknock.

Sheet XII. Illustrates Maps 35, 36, and 43 SW., and SE.

Section from the Ebwy River, near Cefn Crib, Monmouth, across the Forest of Dean to Garden Cliff, Gloucester; (Vertical Section 7 illustrates this sheet).

Sheet XIII. Illustrates Maps 43 NW., NE., and SE., and 55.

Sect. 1. From Edge Hill, Forest of Dean, to Tainton House.—Sect. 2. Across the Silurian District of Woolhope; (Vertical Section 15 illustrates this and the preceding Section).—Sect. 3. Through Keys End Hill and Berrow Hill.—Sect. 4. From near Ledbury, through Sitchwood, over the North point of Swinyard Hill.—Sect. 5. From Old Castle through the Herefordshire Beacon Malvern Hills.—Sect. 6. From Brockhill Copse through the Wych, Malvern Hills.—Sect. 7. From near Hall Court through the Worcestershire Beacon, Malvern Hills —Sect. 8. By Howler's Heath and the Obelisk in Eastnor Park; (Vertical Section 15 illustrates this Section).

Sheet XIV. Illustrates Maps 19 and 35.

Sect. 1. From Pyrton Passage, through Cam Long Down and Uley Bury, to Kingscote Park, Gloucester.—Sect. 2. From the Great Western Railroad, near Saltford Station, to the Box Valley, near Slaughterford; (Vertical Section 11 illustrates this Section).—Sect. 3. From Doddington Park, by Winterbourn, to the Severn Flats, near Chittining Wharf.

Sheet XV. Illustrates Maps 19, 35, and 43 SE.

Sect. 1. From Ridge Barn Hill, near Castle Cary, Somerset, to Jay Hill, near Bilton, Gloucester.—Sect. 2. Through the Coal Measures of the Forest of Dean, Gloucester; (Vertical Section 7 illustrates this Section).

Sheet XVI. Illustrates Map 19.

Sect. 1. From Mere, Wilts, to Vobster, Somerset.—Sect. 2. From the Mendip Hills to Nailsea Station, Bristol and Exeter Railway.—Sect. 3. From Axbridge to Congresbury Moor, Somerset.

Sheet XVII. Illustrates Maps 19 and 35.

Section from Glastonbury Tor, across the Mendip Hills, and by Dundry Hill, Clifton, Bristol, and Blaise Castle, to the Severn Flats, near Compton, Greenfield.

LIST OF VERTICAL SECTIONS,

Illustrative of the Horizontal Sections and Maps of the Geological Survey of Great Britain.

These Sections are arranged, in the form of Vertical Columns, to a scale of 40 feet to an inch, and illustrate such details as it is impossible to give in the Horizontal Sections above described. In the Coal Measure Sections, for instance, the Thickness of each Bed of Coal. the Mineral Structure and Thickness of the Strata with which they are associated, the Nature and Amount of Ironstone, are given in the greatest detail. Price 5s. each Sheet.

SHEET No. 1. Section at Moul, Pembray Trim Saran, Cil Rhedyn, and Mynydd Garreg to the bottom of the Mountain Limestone, Crom Caer Cefn, to illustrate Horizontal Section, Sheet 7, Section 1.

2. The Coal Measures at Llwchwr and Penclawdd, Glamorgan, to illustrate Horizontal Section, Sheet 7, Sec 3.

3.—1. From Werndu Seam of Coal to the two-feet Seam below the Big-Seam, Cwm Afon.—2. At Brondine, Pont Yates, Maenennt, and Yr Hengoed, illustrating the Horizontal Section, Sheet 7, Sec. 2.

4 —1. Lower Coal Measures, North Crop near Llandibie, Carmarthen.—2. Lower Coal Measures, North Crop, at Cwm Twrch, near Ystradgynlas, Brecknock.—3. Forest-fach Level, Cwm Gwendraeth.—4. Section showing the Black Band Ironstone at the Cambrian Iron and Spelter Works, Glamorgan.—5. The Coal Measures at Lansamlet, near Swansea.—6. The Coal Measures at Bryn Coch Dyffryn, Neath, Glamorgan. This sheet illustrates Maps 36, 37, and 41.

5. The South Welsh Coal Measures from Penllergare Glamorgan, to the North Crop, near Tair Carn and Pant-y-gwastad, Carmarthen. This Section illustrates Maps 38 and 41.

6. The Coal Measures from Penllergare to Bishopton, near Swansea, Glamorgan, to illustrate Horizontal Section, Sheet 9, Sec. 1.

7.—1. The Coal Measures at Llangeinor Glamorgan, to illustrate Horizontal Sections, Sheet 10, Sec. 1, 2. and 3.—2. The Coal Measures, Mountain Limestone, and part of the Old Red Sandstone of the Forest of Dean, Gloucester, to illustrate Horizontal Sections, Sheet 12, Sec. 1, and Sheet 15, Sec. 2.

8. The Coal Measures in South Wales and Monmouth.—1. Merthyr Tydfil District.—2. Ebbw Vale.—3. Cwmtelery.—4. Pont-y-Pool District.—5. Risca. This Sheet illustrates Maps 36 and 42 SW. and SE.

9. The lower or Ironstone Coal Measures in Measures in Glamorgan and Monmouth, illustrative of their decrease from Aberdare, east, to Abersychan. This Sheet illustrates Maps 36 and 42 SW. and SE.

10. Diagram, illustrating the Variation of the principal Coal Seams in their range from Merthyr-Tydfil to Pont-y-pool on the North Crop of the Coal Field of South Wales. The Vertical Columns represent the modifications of equivalent Beds in the different localities, each line showing the varied mode of occurrence of some well-known Seams of Coal in such localities. This Sheet illustrates Maps 36 and 42 SW. and SE.

11. The Coal Measures, Carboniferous Limestone, and a portion of the Old Red Sandstone, in the Vicinity of Bristol, to illustrate Horizontal Section, Sheet 14, Sec. 2.

12. Sections illustrative of the Passage of the Old Red Sandstone into the Carboniferous Limestone in South Wales and South-western England, viz. at West Angle, Skrinkle Haven, and Caldy Island, Pembroke; Clydach, Monmouth: Dean Forest; Clifton, Bristol; and Mendip Hills, Somerset. This Sheet illustrates Maps 19, 35, 38, 42 SE., and 43 SE.

13. The Silurian Rocks.—1. The Old Red Sandstone and Silurian Rocks from West Dale Point, Pembroke, Northwards to Marloes Bay.—2. From Gateholme Island to Wooltack Park, Pembroke.—3. Through the lower Silurian Strata, near Llandewi Velfry, in Carmarthen, to illustrate the Horizontal Section, Sheet 2, Sec. 1.—4. Through the lower part of the Old Red Sandstone to the Limestone of Clog-y-fran, near Llandowror, Carmarthen, to illustrate the Horizontal Section, Sheet 2, Sec. 3.—5. The Flagstone Series at Mydrim, North of St. Clare's, in Carmarthen, to illustrate the Horizontal Section, Sheet 2, Sec. 5.

14. The Silurian Rocks.—1. Through the Tilestone and upper and lower Silurian Strata at Golden Grove, near Llandello, Carmarthen, to illustrate the Horizontal Section, Sheet 3, Sec. 2.—2. Through the Tilestone and upper and lower Silurian Strata in the Bed of the Sawdde River, near Llangadoc, Carmarthen, to illustrate the Horizontal Section, Sheet 3, Sec. 3.

15. The Silurian Rocks.—1. Through the Silurian Strata of May Hill, Gloucester, to illustrate the Horizontal Section, Sheet 13, Sec. 1.—2. From the Old Red Sandstone, through the Silurian Strata of Woolhope, in Hereford, to illustrate the Horizontal Section, Sheet 13, Sec. 2.—3. From the Old Red Sandstone to the Syenitic Rocks of the Malvern Hills, to illustrate the Horizontal Section, Sheet 13, Sec. 8.

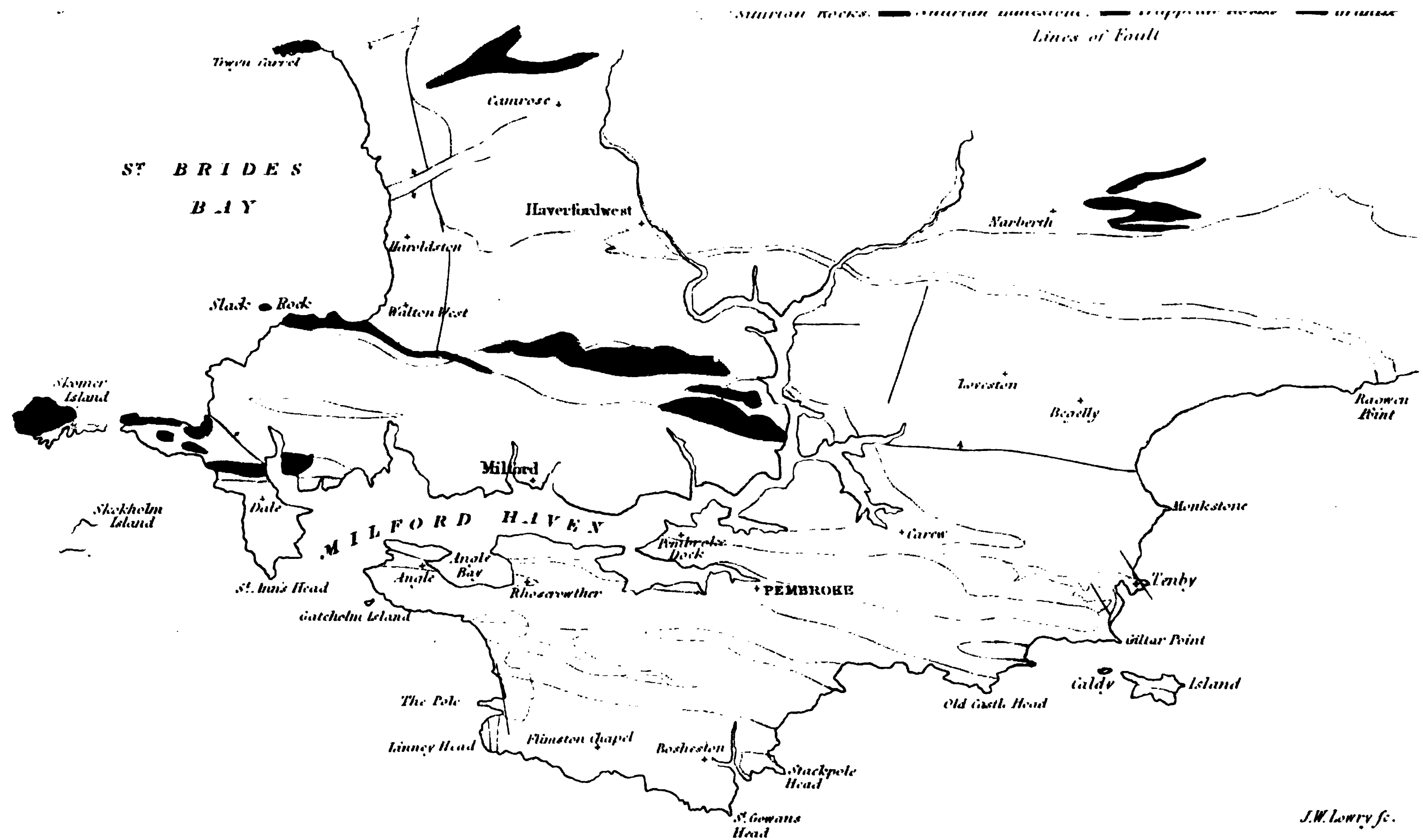
BOOKS published by Messrs. Longman and Co. connected with the Geological Survey.

REPORT on CORNWALL, DEVON, and WEST SOMERSET. By Sir H. T. De la Beche, F.R.S. &c. 14s.

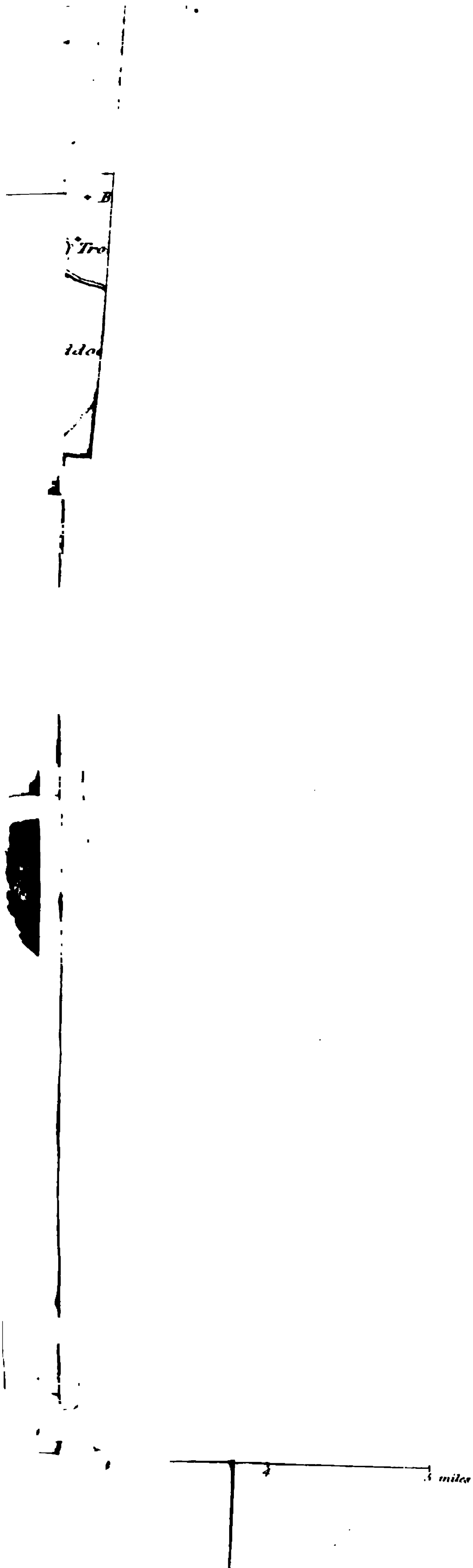
FIGURES and DESCRIPTIONS of the PALÆOZOIC FOSSILS in the above COUNTIES. By Professor Phillips. 9s.

REPORT on LONDONDERRY and Parts of TYRONE and FERMANAGH. By J. E. Portlock, F.R.S. 24s.

London:—Printed by W. Clowes and Sons, Stamford Street, for Her Majesty's Stationery Office.



Lines of Fault
S.T BRIDES BAY
Haverfordwest
Camrose
Haroldston
Walton West
Slack Rock
Skomer Island
Skokholm Island
Dale
St. Ann's Head
Gatcholm Island
MILFORD HAVEN
Milford
Angle
Angle Bay
Rhoscrowther
Pembroke Dock
PEMBROKE
Carew
Narberth
Loveston
Begelly
Monkstone
Tenby
Giltar Point
Caldy Island
Old Castle Head
Stackpole Head
St. Gowans Head
Bosheston
Flimston Chapel
Linney Head
The Pole
J.W. Lowry fc.

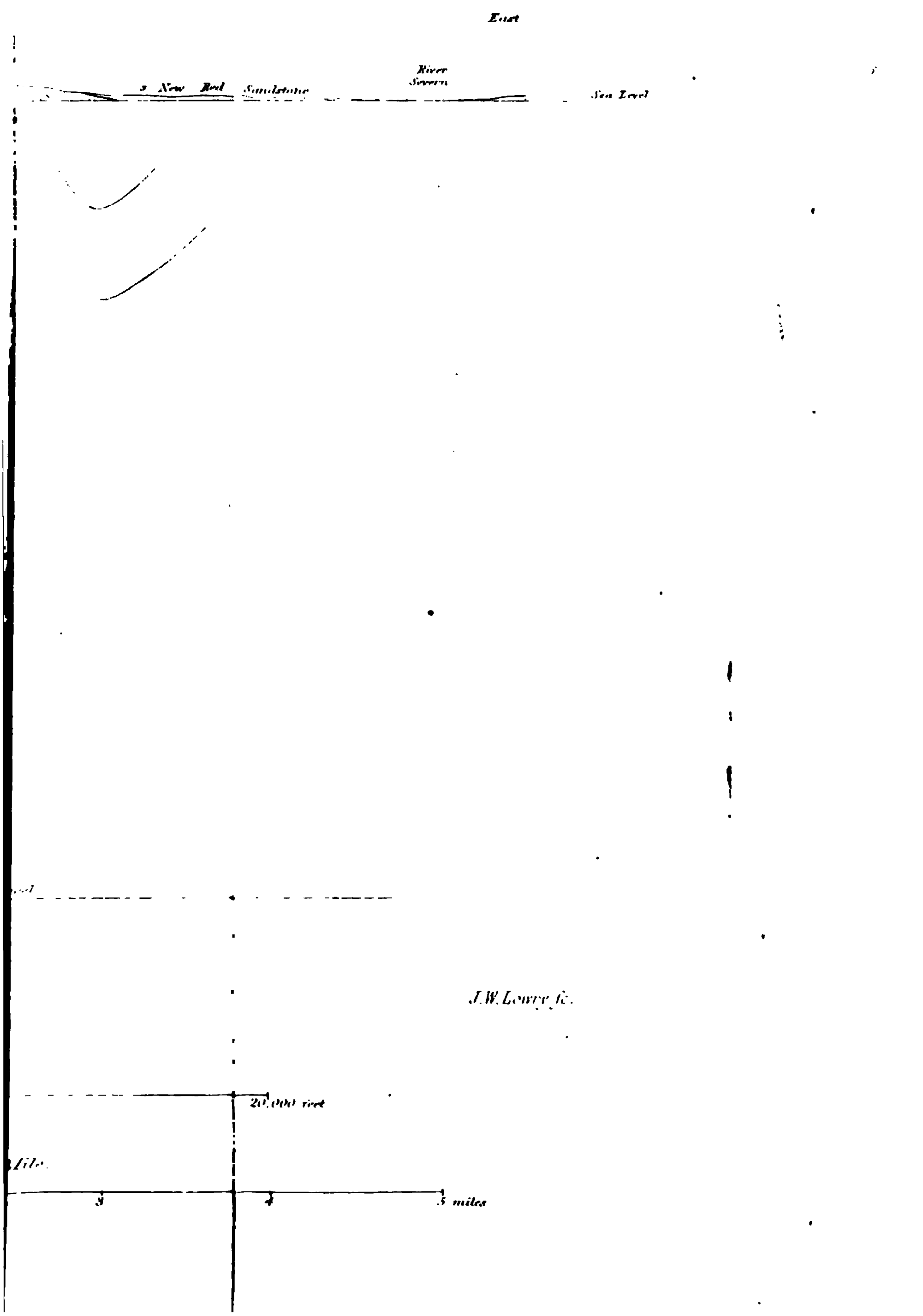

miles

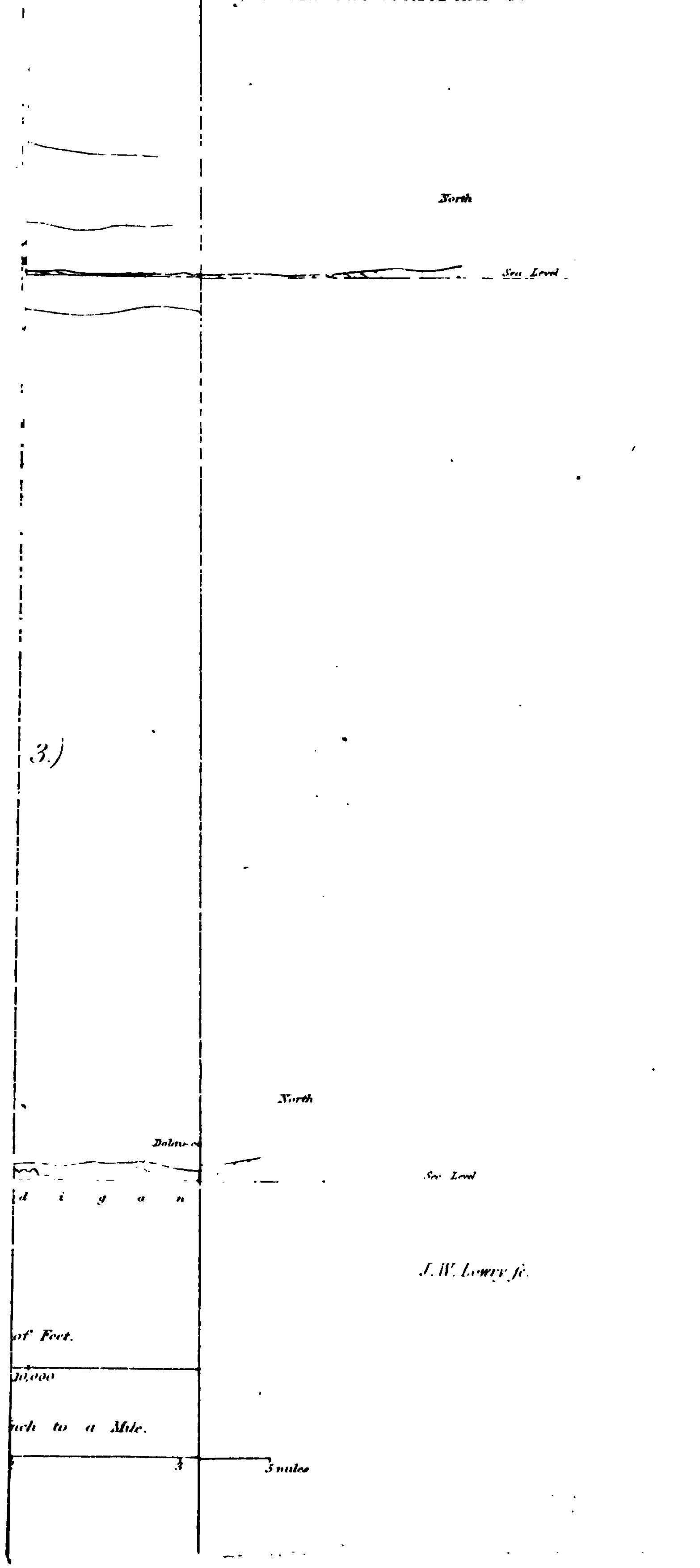
Geological Memoirs Vol. I. Pl 3

J. W. Lowry fc.

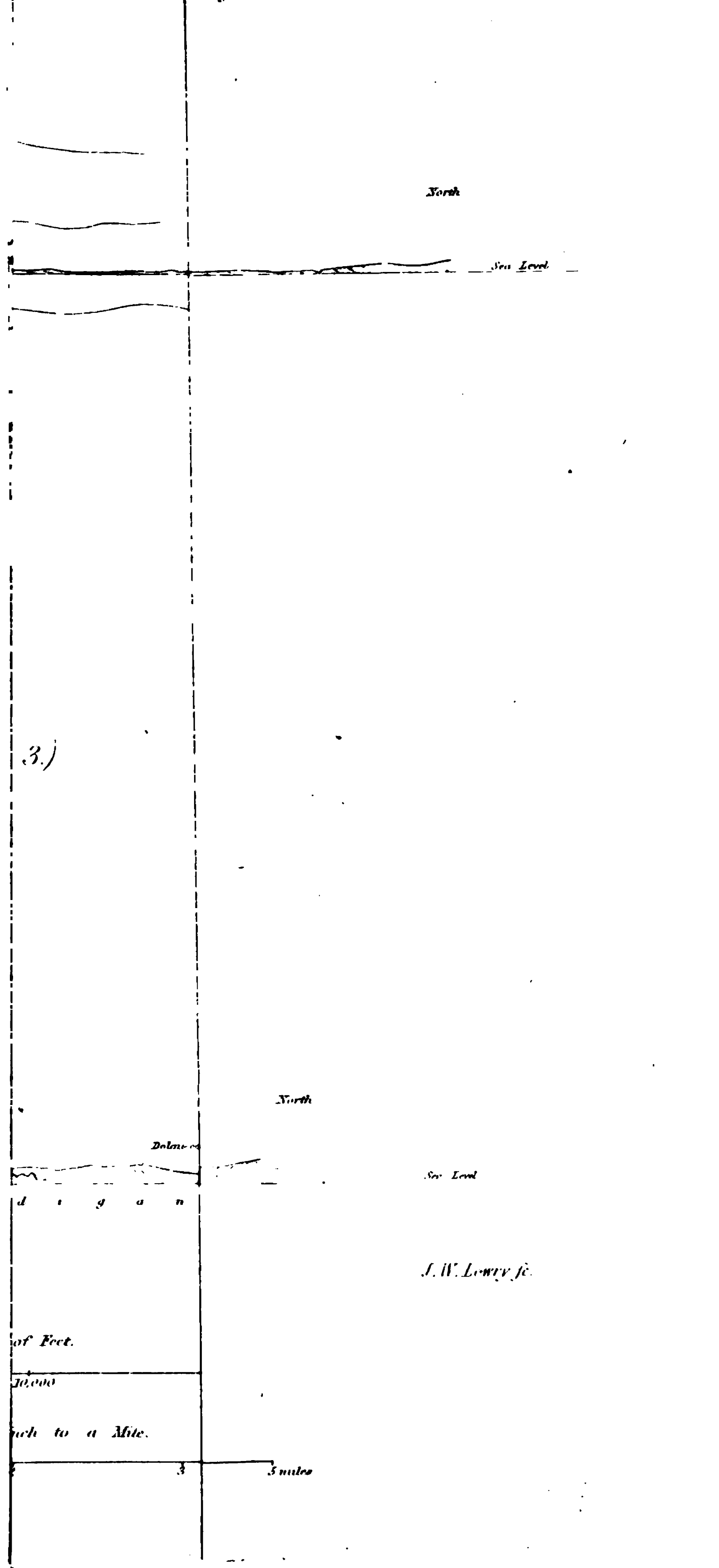
5 miles

Geological Memoirs Vol. I. Plate 4

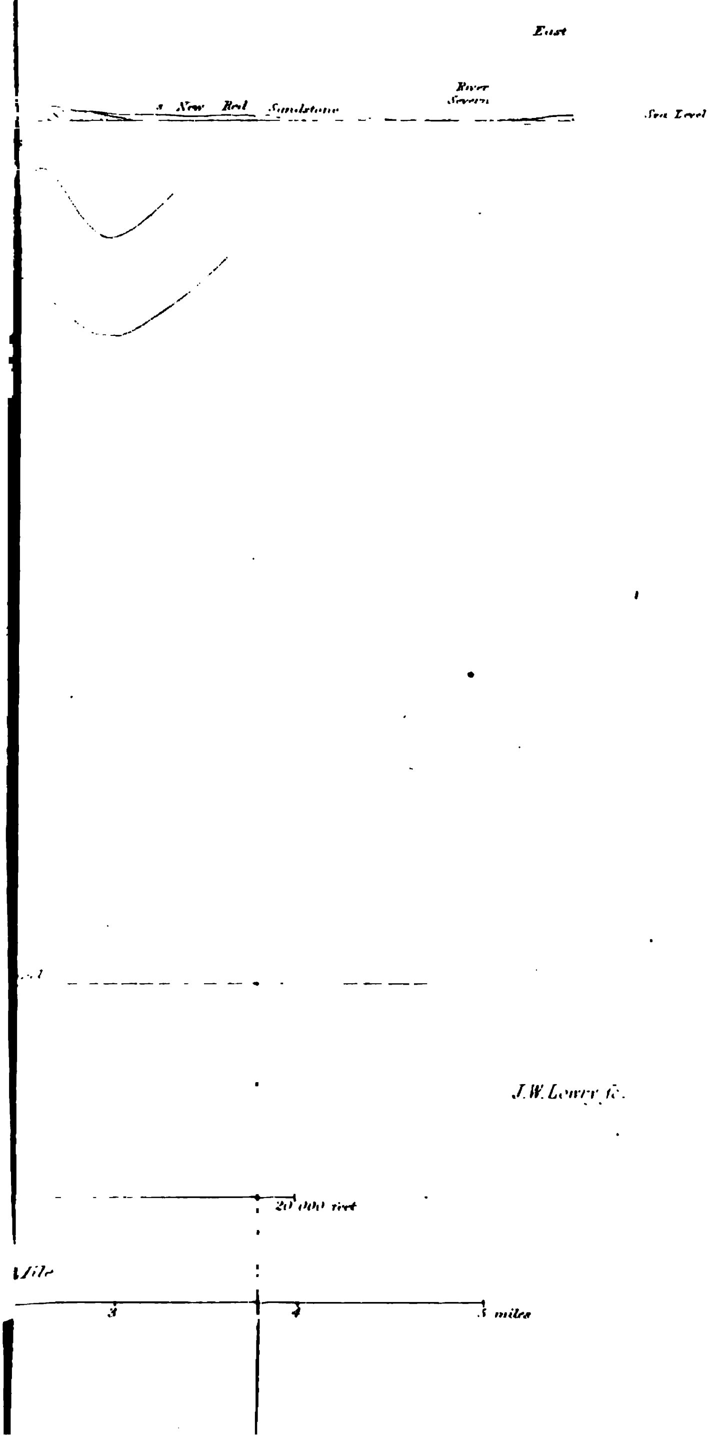



North
Sea Level
3.)
North
Dolme
Sea Level
d i g a n
J. W. Lowry fc.
of Feet.
10,000
ich to a Mile.
3
5 miles

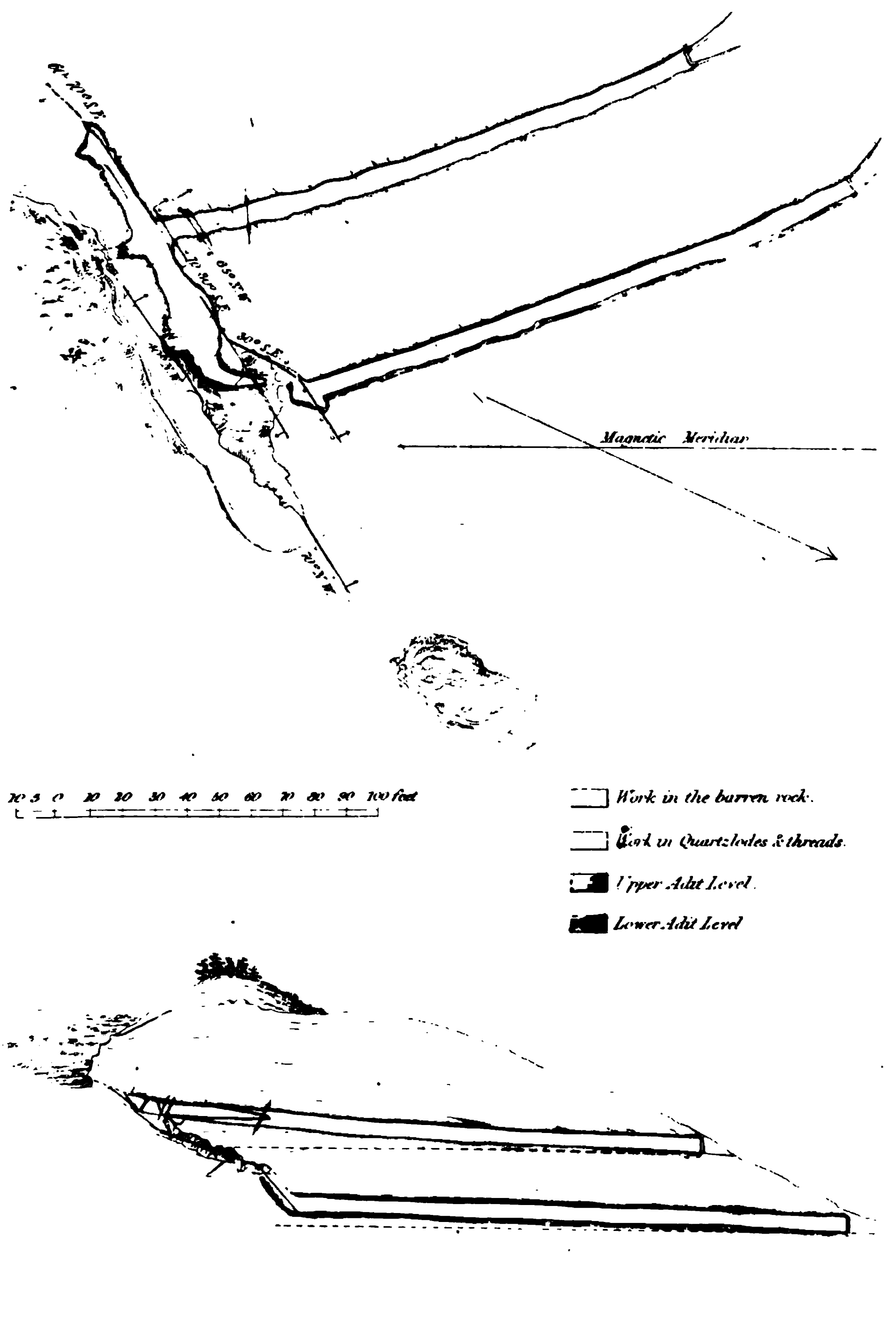
ological Memoirs Vol. 1. Plate 5.



J. W. Lowry fc.


East
River
Severn
New Red Sandstone
Sea Level
J.W. Lowry fc.
20,000 feet
Mile
3
4
5 miles

PLAN & SECTION
of the South Western part of the
ROMAN MINING WORKS CALLED GOGOFAU
LLANPUMPSANT, CAERMARTHENSHIRE.



W. W. Smyth 1844 J. W. Lowry Sc.